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ON THE STARCH OF EVERGREEN LEAVES AND ITS RELATION TO PHOTOSYNTHESIS DURING THE WINTER.

KIICHI MIYAKÉ.

SACHS[1] suggested that in evergreen leaves the starch included in the chloroplasts might be stored there throughout the winter, but it seems that he did not make any observations of it. Mer,[2] by examining the contents of some evergreen leaves, found that the starch disappears at the end of October, to reappear again during the next March. Haberlandt[3] states that he found few starch granules in the palisade parenchyma of the leaves of *Taxus baccata* in winter.

Schulz[4] made a more extended study of the reserve materials of evergreen leaves in winter. He examined about a hundred species of plants, comprising both gymnosperms and angiosperms. All of the gymnosperms studied were found to be free from starch except *Gnetum Gnemon*, in which the green cells contained some starch-granules. Among the angiosperms all monocotyledons and some dicotyledons were free from starch, while the remaining dicotyledons contained more or less starch in the leaves. In many species, however, the starch was found only in

[1] SACHS, J., Microchemische Untersuchungen. Flora **20**: 289. 1862. (p. 300.)

[2] MER, E., De la constitution et des fonctions des feuilles hivernales. Bull. Soc. Bot. France **23**: 231. 1876.

[3] HABERLANDT, G., Vergleichende Anatomie des assimilatorischen Gewebesystems der Pflanzen. Jahrb. Wiss. Bot. **13**: 74. 1882.

[4] SCHULZ, E., Ueber Reservestoffe in immergrünen Blättern. Flora **71**: 223. 1888.

the fibrovascular bundles and the surrounding tissues. It was only in *Viscum album* and *Euonymus japonicus* that the green cells of the leaves contained some starch. More recently Lidforss[5] in examining the leaves of several winter-green plants, comprising herbs, shrubs, and trees, came to the conclusion that all green cells of plants are entirely free from starch during the winter months.

It seems, therefore, according to the observations of the above investigators, that almost all of the evergreen plants of northern and middle Europe lose the starch from the green cells of the leaves during winter. To know whether a similar state of things holds true in Japan, and to throw some light on the relation of leaf-starch to photosynthesis, I undertook the present investigation at the suggestion of Professor M. Miyoshi, to whom my sincere thanks are due for kind suggestions and helpful criticisms. The work was carried on in the Botanical Laboratory of Tokyo Imperial University, from August, 1898, until June of the following year.

There are various methods of testing for starch, all using iodine as the principal reagent. After some trials I determined to use Meyer's iodine-chloral method.[6] The leaves to be examined were directly observed, or kept in alcohol (70 per cent.) until examined. When fresh leaves were used, several thin sections were made from each of them, and placed in strong alcohol until the decoloration was complete. They were then placed on the slide, a few drops of chloral-iodine and potassium-iodide solution[7] being added, and examined under the microscope. When alcoholic material was used, the sections were immediately placed on the slide for examination.

Among the climatic factors the temperature plays an important part in the process of photosynthesis, and it would not be superfluous, before entering upon the account of my researches,

[5] LIDFORSS, B., Zur Physiologie und Biologie der Wintergrünen Flora. Bot. Centralb. **68**: 33. 1896.

[6] MEYER, A., Das chlorophyllkorn. Leipzig, 1883.

[7] Prepared by mixing equal quantities of chloral-hydrate and water, to which a little iodine and potassium-iodide were added.

to make a short statement regarding the temperature of Tokyo and other parts of Japan during the winter.

Tokyo is situated in about the middle portion of the main island of Japan, 35°59′ N., 139° E. In January, the coldest month of the year, the temperature at night often falls several degrees below zero centigrade, but rises sometimes to 10° C. during the day. The mean average temperature of the three winter months in Tokyo, taken from the observations of the last twenty years in the Central Meteorological Observatory, is as follows: December, 5°.1;[8] January, 2°.7; February 3°.5. The winter of 1898–99 was a little milder than usual, the record being as follows: December, 6°.4; January, 3°.2; February, 4°.2.

The following table shows the mean temperature of several stations from which the alcoholic specimens of evergreen leaves were sent to me for examination:

Station	Location	Long. and Lat.	Dec.	Jan.	Feb.
Kumamoto ..	Kiushu island, southern Japan	32° 48′ N. 126° E.	6°.2	4°.4	5°.6
Kyoto[9]	Middle Japan	35° 1′ N. 136° E.	4°.2	2°.3	2°.7
Ishinomaki[10]	Northeastern Japan	39° 16′ N. 139° E.	2°.7	−0°.8	0°.2
Sapporo.....	Hokkaido island, northern Japan	43° 3′ N. 138° 5′ E.	−3°.1	−6°.3	−5°.0

For comparison I give the mean temperature for January in several localities of Europe and America:

Berlin, − 0°.8[11]	London, 3°.5	New York, − 1°.0
Munich, − 3°.0	Edinburgh, 3°.0	Washington, 0°.2
Hamburg, − 0°.4	Dublin, 4°.7	Boston, − 3°.4
Vienna, − 1°.7	Paris, 2°.0	Chicago, − 5°.0
Stockholm, − 3°.7	Marseilles, 6°.4	St. Louis, − 0°.5
Kopenhagen, − 0°.4	Rome, 6°.7	Montreal, −8°.4

[8] Throughout the paper temperature is expressed in centigrade.

[9] No meteorological station was found at Nara, where the material was collected, so I give the record of Kyoto, about twenty miles from Nara, and probably with nearly the same temperature.

[10] For the same reason as above I give the record of Ishinomaki, about twenty-five miles from Sendai, where my material was collected.

[11] These figures were taken from J. Hann, Handbuch der Klimatologie. 1883.

STARCH CONTENTS OF EVERGREEN LEAVES DURING THE WINTER AND AT OTHER TIMES.

I first examined a number of evergreen plants, including angiosperms, gymnosperms, and pteridophytes, for the starch contents of the leaves in August. The results generally correspond to the investigation of Meyer.[12] Thus, generally speaking, monocotyledons have little or no starch in the leaves, while dicotyledons, gymnosperms, and pteridophytes are found to be fairly rich in starch.

Then, during several months, from August to the following spring, I examined about eighty evergreen plants for their leaf-starch, the material being usually taken twice or three times a month. The leaves for examination were taken from various parts of the plants, the healthy and full-grown ones being selected. In many cases they were taken from several individuals of the same species. To determine the starch contents four to eight cross-sections were made from a single leaf, and for such sections five to ten leaves were used. Of eighty species examined the following seventeen were found to lose the starch from the mesophyll during the coldest part of the winter:

Ilex rotunda.
Ilex latifolia.
Magnolia compressa.
Magnolia grandiflora.
Ternstroemia japonica.
Daphne odora.
Andromeda japonica.
Aucuba japonica.
Geranium acutarium.*
Asarum Blumei.*
Ephedra vulgaris.
Picea hondoensis.
Podocarpus Nageia.
Aspidium falcatum.*
Polypodium ensatum.*
Polypodium lineare.*
Gymnogramme japonica.*

* Herbaceous plants.

As it takes too much space to describe the results with all the species above mentioned, I shall give only those with *Ilex rotunda*, as a representative.

[12] MEYER, ARTH., Ueber die Assimilationsproducte der Laubblätter angiospermer Pflanzen. Bot. Zeit. **43**: 417. 1885.

ILEX ROTUNDA.

Date	Pal.[13]	Spon.	Stom.	M. t.[14]
1898, August 19	3–4[15]	3–4	II[16]	27.9
September 8	3–4	3–4	II	23.2
October 14	3–4	3	II	17.9
" 20	3–4	3	II	13.0
November 7	3–4	3	II	10.9
" 19	3	3	I	11.9
" 24	2	2	I	7.0
December 2	2	2	I	9.7
" 8	2	2	I	8.1
" 23	1	1	O–I	−0.9
1899, January 9	1	1	O–I	3.5
" 16	0–1	0–1	O–I	−1.2
" 31	0	0	?	3.0
February 8	0–1	0–1	O–I	4.5
" 27	2	2	I	8.5
March 6	3	3	I	8.9
" 29	4	4	I	12.7
April 25	5	5	I	13.9

The following twenty-seven species were found to contain very little starch in the mesophyll during the coldest time of the year:

Citrus Aurantium Bergamia.
Ilex crenata.
Thea japonica.
Thea sinensis.
Thea Sasangua.
Eurya ochnacea.
Nandia domestica.
Berberis napalensis.
Myrica rubra.
Photinia glabra.
Rhaphiolepis japonica.
Laurus nobilis.

[13] The following abbreviations are used in the tables: *pal.*, palisade parenchyma; *stom.*, stomatic guard-cells; *spon.*, spongy parenchyma; *m. t.*, mean temperature. It was found that in many leaves there is some difference in the starch contents between palisade and spongy parenchyma, and hence I have denoted the starch contents of the two regions separately.

[14] The temperatures in this and other tables are taken from the observations made at the Central Meteorological Observatory of Tokyo, which is about one and a half miles from the Botanical Garden, where most of my material was collected. I found that there is very little difference in temperature between the two localities.

[15] In designating the relative quantity of starch in the mesophyll, the following numerical signs are used: *0*, no starch; *1*, very little starch; *2*, little starch; *3*, moderately rich in starch; *4*, rich in starch; *5*, very rich in starch.

[16] The starch in the guard-cells of stomata was examined at the same time, and the amount is shown in the following way: *O*, no starch; *I*, little starch; *II*, rich in starch; *III*, very rich in starch.

Osmanthus fragrans.
Trachelospermum jasminoides.
Hedera Helix colchica.
Dendropanax japonicum.
Quercus Vibrayeana.
Euonymus japonicus.
Thymus serpyllum vulgaris.
Rhododendron Metternichii.
Eleagnus pungens.
Eleagnus macrophylla.
Torreya nucifera.
Taxus cuspidata.
Cunninghamia sinensis.
Sciadopitys verticillata.
Tsuga diversifolia.

In the following table the results with *Thea japonica* are given

THEA JAPONICA.

Date	Pal.	Spon.	Stom.	M. t.
1898, August 19	3	3	I	27.9
September 8	3	3	I	23.2
" 21	4	4	I	20.5
October 13	3–4	4	I	15.3
" 21	2–3	3–4	I	17.3
November 7	2–3	3–4	I	10.9
" 19	2	3	I	11.9
" 24	1–2	3	I	7.0
December 8	2	2	I	8.0
" 25	1	1	I	4.6
1899, January 9	1	1	?	3.5
" 31	1	1	?	3.0
February 8	1	1–2	0	4.5
" 27	2–3	3	0	8.5
March 13	2–3	4	?	4.1
" 23	2–3	4	?	10.4
April 11	4–5	5	I	12.1
" 23	4–5	5	I	15.3

The following twenty-one species were found to contain a little starch (2 in my scale) in the mesophyll during mid-winter:

Osmanthus aquifolium.
Actinodaphne lancifolium.
Gardenia florida.
Serissa foetida.
Rosa indica.
Pasania cuspidata.
Quercus glauca.
Illicium anisatum.
Fetsia japonica.
Skimmia japonica.
Ardisia japonica.
Pittosporum Tobira.
Ilex integra.
Saxifraga sarmentosa.*
Nasturtium officinale.*
Trachycarpus Fortunei.
Thuja occidentalis.
Chamaecyparis obtusa.
Abies firma.
Pinus densiflora.
Pinus Thunbergii.

*Herbaceous plants.

The results with *Osmanthus aquifolium* are as follows:

OSMANTHUS AQUIFOLIUM.

Date	Pal.	Spon.	Stom.	M. t.
1898, August 18	3	3–4	I	27.5
September 8	2-3	3–4	I	23.2
October 10	2	3	O–I	16.8
" 17	2	3	O–I	17.9
November 7	2	3–4	O–I	10.9
" 19	2	3–4	O–I	11.9
" 24	2	2–3	O	7.0
December 8	2	2–3	O	8.0
" 23	2	2–3	O	–0.9
1899, January 9	2	2	O	3.5
" 31	2	2	O	3.0
February 8	2	2	O	4.5
" 27	2	2–3	O	8.5
March 7	3	3–4	O	9.7
" 29	2–3	4	O	12.7
April 15	4	4–5	O	11.8

In the twenty following species, the mesophyll was found to be moderately rich in starch during the coldest period. They are the following:

Distylium racemosum.
Cinnamomum Camphora.
Viscum album.
Nerium odorum.
Daphniphyllum macropodum.
Eriobotrya japonica.
Juniperus chinensis procumbens.
Cryptomeria japonica.
Thuja orientalis.
Podocarpus macrophylla.
Cephalotaxus drupacea.
Thujopsis dolabrata.

The results with *Distylium racemosum* are as follows:

DISTYLIUM RACEMOSUM.

Date	Pal.	Spon.	Stom.	M. t.
1898, August 18	4	4	I	27.5
September 8	4	4	I	23.2
October 21	3–4	4	I	17.3
November 16	3	3	O–I	11.2
" 24	3	3	O–I	7.0
December 8	3	3	?	8.1
" 21	3	3	?	4.1
1899, January 9	3	2–3	?	3.5
" 31	3	2–3	?	3.0
February 8	3	2–3	?	4.5
" 27	3–4	2–3	?	8.5
March 7	4	3	O–I	9.7
" 29	4	4	I	12.7
April 23	5	5	I	15.3

The following table shows the starch contents of *Cinnamomum sericeum* and *Litsea japonica* in autumn, winter, and spring. It will be noticed how rich in starch these two plants are during the winter.

Name	Date	Pal.	Spon.
Cinnamomum sericeum	October 6	3–4	3–4
	January 31	4	4
	April 25	5	5
Litsea japonica	September 7	4–5	5
	January 18	5	5
	April 25	5	5

Thus among eighty species examined, the amount of starch in winter varies greatly in different species, the relation of the starch contents to the number of species being as follows:

Starch contents	0	1	2	3	4	5
Number of species	17	28	21	12	1	1

The majority of the evergreen plants were found to contain more or less starch in the mesophyll during the winter, though the amounts are generally much smaller than those at other times of the year. Only about one-fifth of the whole number of species examined became entirely free from starch, while some species were quite rich in starch during the coldest time of the year.

It can be seen, moreover, that the amount of starch during the winter does not depend much on the family to which the plant belongs. Taking members of Lauraceae, for example: *Laurus nobilis* has very little starch in the mesophyll during midwinter; *Actinodaphne lancifolia* has a little more, *Cinnamomum camphora* is moderately rich, *Cinnamomum sericeum* is richer, while *Litsea japonica* is very rich in starch. However, the mesophyll of all the ferns that I have examined[17] was entirely free from starch in midwinter, although the guard-cells always contain some starch.

Generally speaking, the amount of starch in the mesophyll begins to decrease in November and reaches its minimum during

[17] Besides the species of ferns already mentioned, I have examined *Aspidium varians*, *A. tripteron*, *A. lacerum*, *Pteris serrulata*, and *Lygodium japonicum*, in the coldest time of winter.

January and the beginning of February, increasing again from the end of February. As in the mesophyll, the amount of starch in the guard-cells becomes less or even entirely disappears in winter. Among the plants examined, less than half were found to have the stomata free from starch during midwinter. The increase or reappearance of stomatic starch was found to occur later than that in the mesophyll.

It should be noticed here that the starch contents of evergreen leaves are generally greater in April than in August or September. This fact was already noticed by Mer,[18] who remarked that some unknown internal causes may have an influence on the formation and accumulation of starch besides the known factors.

Lidforss (*l. c.*) noticed that the leaves are quite free from calcium oxalate crystals in winter, and he believes that this is favorable to the economy of plant life, since otherwise they would afford centers for ice-formation within the cells. Although not directly connected with my main object of study, I have examined carefully for the presence and amount of calcium oxalate crystals in the leaves of eighty evergreen plants at different times during the winter. I found the crystals in the majority of dicotyledonous leaves examined, and their amount did not decrease appreciably in winter.

Besides the plants already mentioned, I have examined some green herbaceous plants in the winter time. The results are as follows:

Name	Date	Pal.	Spon.	Stom.
Raphanus sativus	December 25	I	I	I
Raphanus sativus	January 18	I–2	I–2	I
Lamium album	February 12	0	0	I–II
Lamium amplexicaule	January 18	0	0	I
Senecio vulgaris	February 13	0	0	I
Campanula media	January 16	0	0	O
Stellaria media	January 18	I	I	?
Capsella Bursa-pastoris	January 18	2–3	2–3	I–II
Cynara Scolymus	January 18	0–I	0–I	I

[18] MER, E., Influence de quelques causes internes sur la présence de l'amidon dans les feuilles. Compt. Rend. **112**: 248. 1891.

As is shown in the above table, some herbaceous plants contain no starch in the mesophyll in winter, while others retain some. In many of the herbaceous leaves a little starch was found in the guard-cells of stomata.

Some monocotyledonous plants which contain very little or no starch in the mesophyll, but much in the guard-cells during milder temperature, were also examined in winter, and more or less starch was always found in the stomata, as is shown in the following table:

Name	Date	Pal.	Spon.	Stom.
Iris japonica	December 5	0	0	II
Ophiopogon japonicus	January 7	0	0	I
Rhodea japonica	January 7	0	0	III
Aspidistra lurida	January 7	0–1	0–1	II–III

Thus we see that Lidforss's conclusion (*l. c.*) that the green cells of the plant, as well as the guard-cells, are entirely free from starch during winter months does not hold about Tokyo.

I have also examined many evergreen leaves collected in different parts of the country in winter and preserved in alcohol. The results are given below.

Evergreen leaves from Sapporo.

Through the kindness of Professor Miyabe of Sapporo Agricultural College, I have obtained alcoholic specimens of more than thirty species of evergreen leaves of that place, collected on January 22 and 25, and February 16. Among them the mesophyll of the following species was found to be free from starch:

Sciadopitys verticillata.
Pinus Thunbergii.
Pinus Strobus.
Pinus austriaca.
Pinus densiflora.
Picea excelsa.
Abies firma.
Abies sachalinensis.
Thuja orientalis.
Thujopsis dolabrata.
Podocarpus chinensis.
Taxus cuspidata.
Carex rhynchophylla.
Viscum album.
Ilex crenata.
Euonymus japonicus radicans.
Rhododendron brachycarpum.

The following contained little or very little starch in the mesophyll:

Cryptomeria japonica.
Pinus pentaphylla.
Pinus pumila.
Pinus ponderosa.
Picea ajanensis.
Juniperus chinensis.
Chamaecyparis obtusa.
Chamaecyparis obtusa breviramea.
Chamaecyparis obtusa pendula.
Chamaecyparis pisifera.
Chamaecyparis pisifera plumosa.
Ilex latifolia.

Hence we may say that in Sapporo the mesophyll of the majority of evergreen plants is almost free from starch during the coldest period of the winter. The guard-cells were also found to be almost without starch in the majority of the plants examined, about seven or eight species containing a little starch. Five species of dicotyledonous plants were found to contain the crystals of calcium oxalate in the leaves.

Evergreen leaves from Sendai.

The materials for study were sent to me through the kindness of Professor Yasuda of the Second Higher School of Sendai. They were collected on January 21 and February 13, 1899.

Of twenty-three species examined the following fourteen were found to contain no starch in the mesophyll:

Pinus densiflora.
Chamaecyparis pisifera filifera.
Sciadopitys verticillata.
Arundinaria Simoni.
Aucuba japonica.
Iris tectorum.
Rosa indica.
Nandia domestica.
Ilex crenata.
Andromeda japonica.
Euonymus japonicus.
Quercus glauca.
Photinia glabra.
Brassica campestris.

The following contained little or very little starch in the mesophyll:

Abies firma.
Cryptomeria japonica.
Thujopsis dolabrata.
Chamaecyparis obtusa.
Chamaecyparis obtusa breviramea.
Ilex latifolia.
Quercus Vibrayeana.
Thea japonica.
Thea Sasangua.

We may say that in Sendai also the mesophyll of the majority of evergreen plants is almost free from starch during mid-winter. Guard-cells were free from starch in the majority of the examined plants, only five or six species containing a little starch. Calcium oxalate crystals were present, more or less, in almost all the dicotyledonous leaves examined.

Evergreen leaves from Nara.

The material was sent to me through the kindness of Mr. Aizama of the Nara High School, being collected in the cold days of January and February, 1899.

The results of the examination nearly correspond to those obtained from the plants of Tokyo. Among thirty-six species examined the following six contained no starch in the mesophyll:

Podocarpus chinensis.
Maesa Doraena.
Vicia Faba.
Eurya ochnacea.
Ternstroemia japonica.
Symplocos japonica.

Among the rest the following plants were found to contain little or very little starch in the mesophyll:

Podocarpus Nageia.
Pinus densiflora.
Pinus Thunbergii.
Nandia domestica.
Quercus glauca.
Citrus Aurantium Bergamia.
Rosa indica.
Photinia glabra.
Eriobotrya japonica.
Thea sinensis.
Thea Sasangua.
Thea japonica.
Eleagnus pungens.
Daphniphyllum macropodum.
Raphanus sativus.
Osmanthus aquifolium.
Ilex rotunda.
Ilex Oldhami.
Eurya japonica.
Illicium anisatum.
Ficus foveolata.
Raphanus sativus.
Osmanthus fragrans.

The following eight species were more or less rich in starch in the mesophyll:

Abies firma.
Cryptomeria japonica.
Nerium odorum.
Fetsia japonica.
Cinnamomum Loureirii.
Cinnamomum Camphora.
Cinnamomum pedunculatum.
Ardisia japonica.

About one-half of the plants contained some starch in the guard-cells, while calcium oxalate crystals were found in many leaves.

Evergreen leaves from Kumamoto.

The alcoholic specimens of evergreen leaves were sent to me through the kindness of Professor Aida, of the Fifth Higher School in Kumamoto. The leaves were collected at Kumamoto and its vicinity about February 20.

Of thirty-three species examined, starch was absent from the mesophyll of the following three :

Quercus glauca.
Quercus gilva.
Podocarpus macrophylla.

All the rest contained more or less starch in the mesophyll, and the following (more than one-third) were found to be rich or moderately rich in starch.

Citrus Aurantium Bergamia.
Cinnamomum Camphora.
Cinnamomum pedunculatum.
Daphniphyllum macropodum.
Gardenia florida.
Eriobotrya japonica.
Cryptomeria japonica.
Podocarpus chinensis.
Chamaecyparis obtusa.
Abies firma.
Pinus Thunbergii.

The remaining eighteen contained little or very little starch in the mesophyll, and are as follows :

Ilex latifolia.
Ilex integra.
Ilex crenata.
Ilex Oldhami.
Citrus Bigaradia.
Thea sinensis.
Thea japonica.
Euonymus japonicus.
Quercus sp.
Rosa indica.
Ligustrum japonicum.
Raphanus sativus.
Osmanthus fragrans.
Symplocos japonica.
Pasania cuspidata.
Thujopsis dolabrata.
Pinus parviflora.
Juniperus rigida.

Crystals of calcium oxalate were found in many leaves. It must be noticed that these results do not represent exactly that of the coldest time of the year in Kumamoto, as all the materials examined were collected in the latter part of February.

FORMATION AND TRANSLOCATION OF STARCH IN WINTER.

As stated before, many of the evergreen leaves in Tokyo contain more or less starch in winter. A series of experiments was performed to decide whether this starch is the product of photosynthesis going on in winter, or that which was formed earlier and kept there in the mesophyll without translocation. The experiments were mostly made with pot-plants, plants growing in the ground out of doors sometimes being used. The following plants were used in the experiments:

Thea japonica.
Fetsia japonica.
Rosa indica.
Andromeda japonica.
Cinnamomum Camphora.
Quercus Vibrayeana.
Eriobotrya japonica.
Hedera Helix colchica
Ilex crenata.
Osmanthus fragrans.
Pinus densiflora.
Pinus Thunbergii.
Abies firma.
Podocarpus macrophylla.
Chamaecyparis obtusa breviramea.
Cryptomeria japonica.

The experiments were conducted between January 8 and the end of February. First of all, plants which contain more or less starch in the leaves were either put in the dark room [19] or covered with a black cylinder out of doors. After two or three weeks the leaves of most of the darkened plants were found entirely free from starch.[20] Then they were exposed to light. In most cases a small quantity of starch was formed after five to eight hours of exposure; in some cases it took ten to fifteen hours or more. The results of a few experiments are given below:

Thea japonica.

Two pot-plants were used, each about a meter high. On January 23, 1899, several leaves from each plant were examined for the starch contents and treated as below:

[19] During January and February, the temperature of the dark room was found to vary between 1°.0 and 7°.0 C.

[20] In some it took only ten days for the leaves to become free from starch, while in *Cryptomeria japonica* it took more than a month, probably due to the rich starch contents.

	Starch contents[21]			Treatment
A.	1-2	2-3	?	Put into the dark room.
B.	1-2	2-3	?	Remained out of doors as a check.[22]

At 9 A. M., February 10 (m. t. 3°.1, max. 8°.6, min. 2°.6) the leaves of both plants were examined, and it was found that the darkened plant had lost all of its starch in the leaves, while the starch of the check plant remained constant.

Then *A* was exposed to light out of doors. At 5 P. M. of the same day the leaves were again examined and the starch contents were found to be 1–2.

Fetsia japonica.

Two pot-plants, each about two-thirds of a meter high, were used. On January 23 the leaves of both were examined and treated as follows:

	Starch contents			Treatment
A.	3	3	I–II	Put into the dark room.
B.	3	3	I–II	Exposed to light out of doors as a check.

On February 17 the leaves of *A* were found to be free from starch, and the starch contents of *B* had remained constant. At 9 A. M. February 20 (m. t. 3°.4, max. 9°.7, min. −0°.8) the darkened plant was put into the light out of doors. At 5 P. M. of the same day the starch contents of *A* were 2, 2, I–II; and at 5 P. M. February 22 it became 3, 3, I–II.

Cinnamomum Camphora.

A small pot-plant about two-thirds of a meter high was examined for the leaf-starch at 2 P. M. February 9, and at once put into the dark room. The starch contents then were 2–3, 2–3. At 9 A. M. February 20, it was found that all the starch had disappeared from the mesophyll. The plant was exposed to light out of doors at noon of the same day, and at 5 P. M. of the same day the starch was found to be 1–2, 1–2, having been formed within five hours.

[21] The starch contents of palisade and spongy parenchyma, and of the guard-cells are denoted in three separate columns. It is moreover to be noticed that in *Thea japonica* the starch contents of small pot-plants are generally richer than those of the larger tree growing out of doors.

[22] In all experiments, the pots were buried in the ground to prevent the freezing of the earth.

Pinus Thunbergii.

Two pot-plants were used, each about half a meter high. On February 1 starch-contents of the leaves from both plants were examined and treated as below:

	Starch-content		Treatment
A.	3	?	Covered with a black cylinder.
B.	3	?	Check plant not covered.

The two put out of doors side by side.

On February 20 the starch had disappeared from *A*, and that of *B* had remained constant. At noon of the same day *A* was exposed to light, and at 5 P. M. the starch-contents were found to be 1–2, having been formed within five hours.

Abies firma.

Two pot-plants, each about a meter high, were examined for the leaf starch on January 23 and treated as follows:

	Starch-content			Treatment
A.	2–3	2–3	I	Put into the dark room.
B.	2–3	2–3	I	Remained out of doors as a check.

At 9 A. M., February 10, the mesophyll of *A* was found to be entirely free from starch. After exposure to the light out of doors, at 5 P. M. of the same day the starch was 1–2, 1–2, I; and at 5 P. M., February 11, the starch had increased to 3, 3, I.

In addition to these plants, several leaves of the following trees, which contain some starch in the mesophyll, were covered with tinfoil in the beginning of February: *Thea japonica*, *Quercus Vibrayeana*, *Sciadopitys verticillata*, *Osmanthus fragrans*, and *Ilex integra*. After two or three weeks the leaves were found to be entirely free from starch.

These experiments suffice to prove that many of the evergreen plants in Tokyo can form starch in the leaves by photosynthesis, and translocate it to other parts of the plant-body during the winter, though these processes may of course be much more feeble than at other times of the year. Hence the starch found in many evergreen leaves in winter may be considered as that which is formed during that season by photosynthesis.

BEHAVIOR OF STOMATA IN WINTER.

The continual exchange of gases between the intercellular spaces of the leaf and the surrounding atmosphere is necessary for photosynthesis, and this interchange is mainly through the stomata. Therefore, if the stomata be tightly closed, the photosynthetic process may practically be stopped in spite of favorable temperature and illumination.[23] Hence it would not be superfluous to note, the opening and closing of the stomata of evergreen leaves in winter, as observed in Tokyo.

Stahl[23] showed, in accordance with Schwendener[24] and Leitgeb,[25] that the stomata of evergreen leaves are closed during the winter, and also that the closed stomata of Taxus and Mahonia open after being kept for a week in a warm room, while those of Buxus and Hedera open after ten days. A similar fact was observed by Lidforss (*l. c.*) in the case of Saxifraga, Iris, and Lilium.

Darwin[26] verified the closure of the stomata of evergreen leaves in winter with his newly devised horn hygroscope. But he mentions some exceptional cases where they were found clearly open on January 20 (temperature 12°.5) in the warm winter of 1897–8, in *Prunus Laurocerasus*, *P. Lusitanica*, *Hedera Helix*, *Capsella Bursa-pastoris*, and *Cheiranthus Cheiri;* while *Buxus sempervirens* and *Ilex Aquifolium* had closed stomata.

For testing the opening of stomata I have adopted Stahl's cobalt test. The leaves, after removal, were brought immediately into the laboratory, the temperature of which varied from 15° to 17°, and covered with dried light-blue cobalt paper,[27] protected on both sides from the moisture of the air by two glass plates.

[23] STAHL, E., Einige Versuche ueber Transpiration und Assimilation. Bot. Zeit. 52 : 117. 1894.

[24] SCHWENDENER, S., Ueber Bau und Mechanik der Spaltöffnungen. Monatsb. Akad. Wiss. Berlin, 833. 1881.

[25] LEITGEB, H., Beiträge zur Physiologie der Spaltöffnungsapparate. Mittheil. Bot. Inst. Graz 1 : 1886.

[26] DARWIN, F., Observations on stomata. Phil. Trans. Roy. Soc. London Bot. 190 : 531. 1898.

[27] Prepared by soaking the filter paper in 2–4 per cent. cobalt chloride solution.

At 1 P. M., January 24, 1899 (half cloudy, temperature outside 7°), four plants were examined. The results are as follows:

Name	Observed facts	Stomata
Ternstroemia japonica.....	Reddening of cobalt paper took place within a few minutes on the under side of the leaf, while it remained blue on the upper for a long time.	Distinctly open.
Thea japonica.....	Very faint reddening seemed to occur after some time, but it is doubtful.	?
Fetsia japonica.....	Same as preceding.	?
Sciadopitys verticillata.....	No reddening occurred on either side.	Closed.

At 2–2:30 P. M. January 31 (clear, temperature 6°), the following plants were examined:

Name	Observed facts	Stomata
Raphiolepis japonica.	Young leaf—cobalt paper quite red after two minutes.	Distinctly open.
	Old leaf—no reddening after thirty minutes.	Closed.
Ternstroemia japonica	Quite red after three minutes.	Distinctly open.
Osmanthus fragrans..	Reddening clearly seen after six minutes.	Open.
Sciadopitys verticillata	No reddening for a long time.	Closed.
Pinus densiflora.....	Reddening after four minutes.	Open.
Quercus glauca.....	Reddening clearly seen after four minutes.	Open.
Quercus Vibrayeana..	Reddening clearly seen after five minutes.	Open.
Quercus phillyraeoides	Reddening after five minutes.	Open.
Pasania glabra.....	Reddening after five minutes.	Open.

At 2 P. M. February 1 (rather clear, temperature 7°.5), the above four species of Fagaceae were examined again, and it was found that all of them had the stomata open as before.

The next day at 3 P. M. (temperature 8°), the following observations were made:

Name	Observed facts	Stomata
Thea japonica, *a*	Faint reddening after some time, but rather doubtful.	?
Thea japonica, *b*	Same as above.	?
Thea japonica, *c*	Reddening clearly observed within ten minutes.	Open.
Juniperus chinensis procumbens	Reddening after a few minutes.	Open.

It is to be noticed that in *Thea japonica* the leaves from the first two plants showed no distinct opening of stomata, while those from the third plant had open stomata. It seems, therefore, that there are some variations in the behavior of stomata of the same species, probably due more or less to the location of the plants.

It is evident that many of the evergreen leaves examined have stomata more or less open in day time during the winter.

SUMMARY.

1. The starch contents of evergreen leaves differ much at a given time according to the different species. Monocotyledons generally contain less starch than dicotyledons, gymnosperms, and pteridophytes, or even none in some species.

2. The starch in evergreen leaves, generally speaking, begins to decrease in November, reaching its minimum during January and the beginning of February, and increases again from the end of February.

3. Many evergreen leaves in Tokyo and other parts of middle and southern Japan contain more or less starch in the mesophyll, while it is entirely absent in some species in the coldest time of winter.

4. The starch found in evergreen leaves in winter is generally very little compared with that observed at other times of the year, but in a few species the starch is quite abundant.

5. This starch is formed by photosynthesis in winter, though feebly, and its translocation occurs in the same season.

6. The starch in the guard-cells becomes less or even entirely disappears in many species, while a few species contain a moderate amount throughout the winter.

7. The majority of evergreen leaves in the northern part of Japan nearly lose the starch from the mesophyll and guard-cells in winter, while a little starch is still found in some species.

8. The starch content of evergreen leaves is generally more abundant in spring than in late summer or early autumn.

9. The opening of the stomata in winter was observed in some evergreen leaves in Tokyo.

10. The entire absence of calcium oxalate crystals from the leaves in winter, as stated by Lidforss, could not be verified in the present investigation.[28]

CORNELL UNIVERSITY,
Ithaca, N. Y.

[28] A preliminary note, bearing the same title as this paper, was published in Bot. Mag. Tokyo 14:44. 1900.

THE RHEOTROPISM OF ROOTS.

FREDERICK C. NEWCOMBE.

(WITH FIFTEEN FIGURES)

(*Concluded from p. 283.*)

VI. LOCATION OF THE SENSITIVE AREA.

SEVERAL experiments were made by Juel[11] to locate the sensitive area. His tests were of two kinds. He cut off the apical 1.5^{mm} of the root of *Vicia sativa*, exposed the seedlings thus prepared to the water current, and found that rheotropic curves followed somewhat more promptly and with greater angles than in uninjured roots. So many seedlings were employed, and the responses were so uniform, that we are probabably justified in accepting the results as demonstrating a rheotropic sensitiveness of the roots in the absence of the apex. Juel's other device consisted in covering the apical portion of roots with caps of collodion. These caps varied from 2 to 7 or 8^{mm} in length. Sufficient experiments were made with the shorter caps to show that the root was sensitive throughout its elongating zone. With the caps 7 to 8^{mm} long only six roots were tested, and of these only two gave reliable positive curves, two remaining straight, and two growing through the collodion and bending positively. Juel explains the curves with collodion caps as due either to the pressure of the water being felt through the collodion or to the penetration of the water stream through the collodion.

1. *Experiments with water-jets.*

My first series of experiments to determine the extent of the sensitive area was made by the employment of fine jets of water directed against various small areas of the root. Each seedling used was fixed by wet cotton in a perforation in a cork closing the lower end of a short glass cylinder 1.5 to 3^{cm} in height. The seedling thus projected both above and below the cork. Its upper part was packed in wet cotton, while 5 to 10^{mm} of its

[11] Untersuchungen über den Rheotropismus der Wurzeln. Jahrb. Wiss. Bot. 34:507.

root projected for the application of the water-jet. At frequent intervals water was put into the small cylinder, and this slowly percolated through the cotton and ran down over the root, thus insuring constant moisture. The water-jets were secured by bringing the water from an elevated reservoir through glass and rubber tubes to small glass nozzles passed through corks which were adjustable in height on small movable standards. The water-jets as they left the nozzles were from 0.2 to 0.5^{mm} in diameter. Each jet was adjustable by a screw-clamp applied to the conducting rubber tube.

This method would seem to offer a somewhat delicate means of locating the sensory area of the root. The majority of roots gave a positive response, but most of the roots did not grow very well. This behavior may be ascribed to various factors. In spite of the precautions taken, the exposed roots of the seedlings were not always everywhere kept covered with moisture; the nutations of the roots made it extremely difficult to keep the water-jet on a precise area, though the experiments were constantly watched and readjustments made; and it was practically impossible always to keep the water stream from circling around the root, thus greatly extending the root surface exposed to the water stream. Besides these objections, it may be well to note that a fine water-jet properly meeting the root affects only a very small surface, and it may be that a larger area must be stimulated to bring forth a ready response. The following table will present the main features of results obtained when the water-jets were applied to the apical millimeter of the root-tips.

TABLE VIII.

GIVING RESULTS OF WATER-JETS APPLIED TO THE APICAL MILLIMETER OF THE ROOT.

Species	Period	Number of roots	+ Curves	− Curves	Neutral
Helianthus annuus ...	7 hours	4	4	..	..
Brassica alba.....	4 to 6 hrs	14	6	2	6
Totals.....	.....	18	10	2	6

That the relatively small number of positive responses in the foregoing tests with *Brassica alba* does not necessarily indicate a lack of sensitiveness in the root-tip is shown by results following the application of the water-jet to the elongating zone, this part having been proved sensitive by Juel's work as well as my own. In one experiment with the highly sensitive *Brassica alba*, the water-jet met the root 2 to 5^{mm} above the tip, yet after a period of twelve hours, of the six roots only two were positive, while one was negative and three were neutral. However, in a total of four experiments of this nature with *Brassica alba*, the seventeen roots showed twelve positive, two negative, and three neutral. This is certainly less equivocal than the results obtained from the same species when the water-jet was applied to the apex.

In conclusion it may be said that the experiments with the water-jets have indicated a rheotropic sensitiveness for the apical millimeter of the root.

2. *Experiments with cylinders of paper and of collodion.*

Another series of experiments to locate the sensitive area was tried with cylinders of paper and others of collodion, in which were cut apertures to admit the streaming water. *Fig. 14* shows the form of these devices. The paper cylinders were made of thin paper held in form by paraffin, and the bottom closed by a bead of paraffin. The collodion cylinders were cast over small rods of sugar, the sugar being subsequently dissolved out by immersion in water. To prepare these rods commercial cane sugar was dissolved by heat and rolled into small rods between the hands. These were then rolled to the desired diameter between plates of glass. Apertures were cut at any desired location in these cylinders, a vane was attached to the upper end to keep the cylinder in a constant position, and enough paraffin applied to make the whole slightly buoyant in water.

FIG. 14.—Illustrating the construction of collodion and paper cylinders used in locating the sensitive area.

These cylinders or stockings were slipped over immersed roots as the seedlings were suspended over basins of water like those already described. When the basin was set in revolution, the stockings behaved well, but results were not forthcoming. The failure was probably due in part to the interference of the cylinders with the direction of the water stream, and in part to their mechanical interference with the curving of the roots.

3. *Experiments with glass tubes.*

The third and most satisfactory method for determining the extent of the sensitive area was the employment of glass tubes of several patterns, by means of which definite parts of the roots were exposed to the water streams in the revolving glass basins, and definite parts were shielded from the streams. The experiments are divided into two groups, those testing the sensitiveness of the apical millimeter or millimeter and a half, and those testing the rest of the root.

a. Testing the sensitiveness of the apex of roots.

To determine the sensitiveness of the apex of roots, straight glass tubes 3 to 4 ^{cm} in length and 3 ^{mm} internal diameter were used. Seedlings of suitable size, usually not more than a half centimeter longer than the tubes, were selected for experiment. The tubes were held in water and the seedlings passed in, after which a little wet cotton was pressed in around the seedling by the use of a needle whose point was broken off. The cotton was pressed in firmly enough to hold the seedling in position, yet not too firmly, to allow the seedling to be moved up or down the tube. Preparations thus made were fastened to bars of wood by means of strips of blotting paper and rubber bands, as shown in *fig. 15*. The bar of wood, with its load, was next suspended with the glass tubes dipping into water in a glass basin on a centrifuge, the seedlings were carefully adjusted so that their tips projected 0.5 to 1 ^{mm} from the glass tubes, and the revolving apparatus was set in motion. In recording the results given below, data as to temperature and velocity will be omitted.

Each could be given, but it will be sufficient to say that temperature was in each case from 21 to 26° in water, and the velocity of water current was from 150 to 500^{cm} per minute.

With *Zea mays* (popcorn) three experiments were made. In the first, eleven roots were used. The tips were never allowed to project from the glass tubes more than 2^{mm}. Every half hour, or oftener if necessary, the roots were pulled up a little to bring them back to 1^{mm} of exposure. After 4 hours, four roots had bent positively with angles ranging from 5 to 20°; the other seven roots were neutral. The second experiment was, in conditions, in every way like the first, except that the period of the test was 8 hours. Ten roots were used, and five of them curved positively with angles of 15 to 20°; the other five roots remained neutral. The five curved roots at the conclusion of the experiment had all bent over in contact with the edges of the glass tubes. The third experiment was quite like the others, except that the roots were not allowed to protrude more than 1.5^{mm} from the tubes, and the period was 7 hours. Ten roots were used, and at the end of the trial six had bent positively and the other four were neutral. One of the responding roots gave an angle of 5°, one of 15°, and four of 20°.

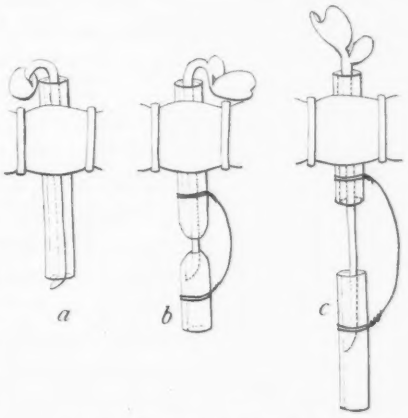


FIG. 15.—Illustrating the use of glass tubes in locating the sensitive area of *Raphanus sativus*: *a*, form of tube used in experimenting with the apex of the root; *b*, form used for exposing a narrow zone; *c*, form used in shielding a long apical section and exposing a long section back of the shielded portion.

With *Raphanus sativus* (Early Long Scarlet), results are still more decisive. In the first group thirteen seedlings were used. In 2¾ hours after the revolution began five roots were positive,

in 5 hours ten were positive, and in 6 hours all thirteen were positive. These roots had never more than 2 mm exposed. Another set of twenty seedlings with 1 to 1.5 mm of the apex exposed gave, after 8 hours, nineteen roots decidedly positive and one neutral. In a third experiment, the roots had a maximum of 1 mm exposed, each root being raised to 0.5 mm of exposed tip as soon as it approached the millimeter limit. Nine seedlings were used, and in 9 hours five roots had become positive, while the other four remained neutral. A final experiment, conducted exactly like the last, gave, after 9 hours, six roots positive with angles of 10 to 20°, while the other four roots remained neutral.

Unless serious objection can be brought against these experiments, they prove that the apex of the root is sensitive to the rheotropic stimulus. It may be objected by some that too much of the root was exposed, so that the elongating zone was affected by the current. This stricture can hardly hold when we consider that in one experiment with *Zea mays* not more than 1.5 mm was exposed, and in two experiments with *Raphanus sativus* not more than 1 mm was exposed. The root cap of this Raphanus has an axial depth of 0.3 to 0.4 mm, so that not more than 0.7 mm back of the cap was exposed, and this amount only for a small fraction of the period of the experiment. It may be thought that possibly there was a current in the tube itself at a greater or less distance above its lower end. This objection has been answered, to some degree at least, by two devices. In one experiment the lower ends of the tubes were contracted so that the root nearly filled the aperture; in the other experiment the space between root and tube was lightly filled with cotton. In both cases good curves were formed. In the first experiment, the bend in the roots took place above the constricted mouth of the tube, while the tip of the root extended obliquely through the narrowed opening. In the second experiment the bend took place in and below the cotton, the cotton not offering a very great resistance. Another answer to the foregoing objection lies in the fact that roots that were kept retracted within the tubes so that their tips were level with the lower end of the

tube never gave any curves. Contact with the side of the glass tube never effected any curvature. Scores of roots have been allowed to grow down through glass tubes, and many have by filling with cotton been pressed against the tubes as the roots grew out through the lower end, yet none have curved in quiet water. If we consider the proportion of the number curving to the total number of roots under experiment, we shall see that there is no ground here for objection to the assumption of the sensitiveness of the root-tip. In *Zea mays* almost half responded positively, and these were almost as many as have, in other experiments with the whole root uncovered, responded in the same time. In *Raphanus sativus* forty-three in fifty-two responded positively. That these curves were responses to the stream of water is readily believed when it is seen that there was not a single case of a negative curve. The curves were all relatively small, because the tubes stopped the progress of the curving; the curves were nevertheless decisive, being usually 15 to 20°, and to the author, who has during the past five years seen thousands of irritable curves in roots, there can be no doubt of the result.

From the foregoing experiments it may safely be concluded that the apex of the root is sensitive to a rheotropic stimulus.

b. Testing the sensitiveness of the root back of its apex.

In order to determine what part of the elongating zone of the root is sensitive, paired glass tubes constructed as shown in *fig. 15, b, c* were used. The tubes were 3 mm in internal diameter, were held together with fine annealed steel wire, and in each paired tube the ends that faced one another were narrowed. The tubes with their contained seedlings were held on supports as in the preceding group of experiments, and adjustments for the desired exposure of the root-surface were made as then, by moving the seedling up or down in the tube. It might be thought that the movement of seedlings up and down the tubes would interfere with results, either by injury to the roots or by bringing a different flank to meet the current. To overcome

this objection the seedlings were in several experiments fastened to the supporting bar by themselves and the encasing tubes were fastened to the same bar by a separate band just below the band holding the seedlings. Such a preparation enabled the glass tube to be moved up or down while the seedlings remained fixed. Results showed that there was no advantage in this more troublesome preparation, and it was discarded as unnecessary.

All of the following experiments were made with *Raphanus sativus* (Early Long Scarlet), the roots of this plant being insensitive to diffused light, and light being necessary at frequent periods of observation.

For the first series of experiments the apical 2 mm of the root were kept below the opening between the two parts of the paired tube, and not more than 2 mm of root were exposed to the water current. In one set of seven seedlings, at the end of 7 hours' revolution, five roots were positive 5 to 40°, while the other two roots were straight. In a second set of six roots, at the end of 4 hours 40 minutes, five were strongly positive, and the sixth root was straight.

These results show that the part of the root just above the apical 2 mm is sensitive.

In the next series of experiments ten seedlings were used whose apex was covered for a distance varying from 3 to 8 mm. Above the covered portion of the root, a portion 5 to 8 mm long was exposed. After 8 hours eight roots were positively bent and two roots were straight.

Five experiments, including forty-eight seedlings, were made, in which 10 mm of the apex of the roots were covered, and the root left exposed for 5 to 8 mm above the covered part. The duration of the experiments varied from 10 to 11 hours. At the end, thirty-four roots were positive, three were negative, and eleven were neutral.

Two experiments, including a total of twenty-three seedlings, were made in which 15 mm of the apex were covered, and 5 to 8 mm above the covered part were exposed. The duration of the experiments was in one case 10 hours, in the other 12¾

hours. Of the twenty-three roots, ten became positive, two negative, and eleven remained neutral.

Two experiments, including nineteen seedlings, were made, in which 20 mm of the apex of the roots were covered, and the roots left exposed for 5 to 8 mm above this portion. One experiment ran for 9 hours, the other for 11 hours. Of the nineteen roots, seven became slightly positive, four slightly negative, and eight remained straight.

The results here recorded are most interesting. They teach that the root is sensitive to the rheotropic stimulus at a considerable distance back of the elongating zone. The elongating zone in this variety of *Raphanus sativus* extends but 5 mm back of the tip. This fact I determined by marking ten roots with India ink, and observing them with a horizontal microscope at intervals during 24 hours. The roots were kept immersed in water. Growth was observed to take place in some roots in the first 4 mm only, and in the others in the first 5 mm. No root showed any elongation of the sixth millimeter. All conditions for growth were favorable, and good growth took place in each root.

Objectionable conditions were in these experiments removed as far as possible. The experiments were all performed within a period of five weeks, the temperature was held within a variation of one degree, the revolution of the basins was the same speed for all, giving in each experiment a range of velocities from 150 to 500 cm per minute, and the duration of the last three series, which are the only ones whose results might *a priori* be called in question, was nearly alike. To lessen the chances, if there were any, of a feeble stream being set up within the tubes themselves, the lower end of the lower tube was in some cases closed with a plug of cotton, in other cases closed by fusing. In still other experiments not only was the lower end of the lower tube closed, but cotton was packed around the root at its entrance into the lower tube. Thus it would seem that all possibility of a current within the tubes was excluded. The closing of the ends of the tubes is, however, not advisable; for

it tends to produce distortion in the roots after 12 to 15 hours of 23° or over. This may come from the lack of oxygen or the accumulation of the excreta of the root. The experiments recorded above, therefore, were performed with open tubes, except for the narrowing at the inner ends, as shown in *fig.* 15. The tips of the roots in all the experiments were kept from 5 to 15 mm removed from the lower open ends of the tubes. In several tests where the whole root was enclosed in a tube, the tip coming even with the lower open end, there was no curvature. The possibility, therefore, of curvature being caused by streams within the tubes may be dismissed.

The experiments show a decreasing sensitiveness in the roots from the region of the elongating zone back to a position at least 15 mm from the apex. When 20 mm of the apex of the root were covered there seemed to be some disturbance of the root but no pronounced directive influence. There were in this case proportionately more than twice as many negative curves as in any other set, while the number of positive curves was much less than in other experiments.

It is worth noting that the percentages of positive curvature in the four different sets show a constant decrease, being 80 per cent. in roots with 3 to 8 mm covered, 71 per cent. in roots with 10 mm covered, 44 per cent. in roots with 15 mm covered, and 32 per cent. in roots with 20 mm covered. The angles attained in these curvatures were often as great as the tubes would allow, and averaged 17° in the first series, 19° in the second, 18° in the third, and 11° in the fourth. Thus it is shown that when 20 mm of the root were covered the positive responses were relatively so few and gave such small angles that one may well suppose that the limit of sensitiveness has been approximated. Not so, however, with the portion of the radish root 15 mm from the tip; of the twenty-three seedlings used, nearly half gave good positive curves, and there were only two negative curves. The small number of negative curves is excellent evidence for the reliability of the result; for the absence of negative curves shows that the positive curves cannot be charged to pathological distortion.

If this evidence is reliable, it shows that the rheotropic stimulus is received and transmitted by a part of the root 10^{mm} removed from the limit of the elongating zone, and 12^{mm} from the part which first curves. Remarkable as this result may seem, I believe it will stand the test of time. One must master a certain amount of technique to obtain success; but the technique once learned, the preparation is easy and the results sure.

C. RESULTS WITH OLDER PLANTS.

1. WITH SECONDARY ROOTS.

It cannot be inferred *a priori* that the secondary roots of non-sensitive primary ones would be found non-sensitive, nor can it be inferred that the secondary roots of sensitive primary ones would be found sensitive. It seems to be true, however, that secondary roots are sensitive or insensitive according to the sensitiveness or insensitiveness of the primary root. Berg[12] found both primary and secondary roots positively rheotropic in *Zea mays*, *Fagopyrum tataricum*, *Tropaeolum majus*, *Lupinus albus*, *L. luteus*, *Vicia faba*, *V. sativa*, and *Helianthus annuus*, while neither order of roots in *Soja hispida* was sensitive. My own results are as follows:

Seven seedlings of *Cucurbita pepo* with short lateral roots protruding were suspended with roots immersed in a basin of water for two days. During this time, the basin was revolved for two periods, once for 24 hours and once for 16 hours. The lateral roots that could be counted as long enough for experiment numbered from thirty-five to forty, the shortest being 1^{cm} and the longest 5^{cm}. The temperature was 24 to 26°, and the velocity of current ranged from 300^{cm} for the slowest to 1200^{cm} per minute for the most rapid flow. All roots, both primary and secondary, grew well and grew straight.

Tropaeolum majus was tested in the same way, but in velocities ranging from 150 to 600^{cm} per minute. Only ten secondary roots were present, and unfortunately the test lasted only 12 hours. All roots grew straight.

[12] Studien über Rheotropismus. Lunds Universitets Årsskrift. 35^{2}: no. 6.

Zea mays (a yellow dent variety) was abundantly employed in several experiments. The seedlings with primary and secondary roots present were suspended in the usual way along the diameter of several glass basins. The temperature varied from 21 to 24° in air, and the velocity ranged from 150 to 600^{cm} per minute. The duration of each test was one week. Some hundreds of secondary and many tertiary roots were present in the latter half of the week. The primary roots, as usual in this species and variety, contorted very badly; the secondary and tertiary roots grew without contortion, and nearly all became strongly positively curved. Only two or three took a negative course, and not more than seven remained neutral.

The secondary roots of *Fagopyrum esculentum* were tested on ten seedlings which had their roots immersed in the water of a revolving basin for 41½ hours. The temperature varied from 23 to 28°, and the rate of flow ranged from 125 to 600^{cm} per minute. There were fifty secondary roots 1^{cm} long or over. Of the secondary roots, fifteen became positive, four negative, and thirty-one did not curve. Of the main roots, seven became positive, one became contorted, and two remained straight.

From the foregoing results one can hardly generalize, because the experiments are too few. Yet it is evident that in the two plants, *Cucurbita pepo* and *Tropaeolum majus*, whose main roots had been found insensitive, or but weakly responsive, to a rheotropic stimulus, the secondary roots are insensitive also; and that in the *Fagopyrum esculentum*, the secondary as well as the primary roots are sensitive, but the former much less sensitive than the latter. For the variety of *Zea mays* used, it may be said that the main roots always contort so badly in water that their relations in rheotropism cannot be determined. Other varieties of *Zea mays* (popcorn and those employed by Jönssen, Berg, and Juel) we know to be positively rheotropic in the main root. The experiments here recorded show the secondary and tertiary roots to be rheotropic also.

II. WITH ROOTS OF MATURING PLANTS.

To obtain the roots of older plants for experiment, special preparation was necessary. Flower pots were chosen of medium size, the bottom broken out and wire netting placed for a bottom. The netting had meshes a little over 2^{mm} in diameter. In these crocks seeds were planted, and the crocks set on a stone slab outdoors, the season being summer. This treatment prevented any great growth of roots through the bottom of the crocks. When the plants had grown to suitable size, the crocks were set into battery jars, the crocks closing the opening of the jars and leaving a free space as a damp chamber below the crocks. The whole preparation was then sunken into the ground, and thus the light was excluded. Such preparations soon gave a good growth of roots down below the crocks. When the roots had attained suitable size, the crocks were lifted out of the jars and set over glass basins with the exposed roots immersed in water. By the revolution of the glass basins, a current of water was generated as in the preceding experiments. The roots that were used in the experiments were probably in no case primary. It is most probable that all primary roots had died at the tip in growing through the bottom of the crock while the crock was sitting on the stone slab.

Hordeum vulgare was used when the plants were 30 to 37^{cm} above ground and were flowering. Twenty-six good roots appeared. The first curves were noted in 20 hours after the revolution of the water basin began. The experiment continued for 50 hours, in air temperature of 24°, and velocities ranging from 100 to 400^{cm} per minute. Twenty-two roots bent positively with angles of 45 to 90°, and four roots remained neutral.

Cucurbita pepo, in the same conditions of temperature and current as Hordeum, was kept in the water stream for 84 hours. The plants were a month old and were in flower. Fifty roots were subjected to the current, but not one bent from a straight course.

Helianthus annuus, a month old, was tested in the same manner as the foregoing plants. There were thirty-two good

roots. Of these, twenty became positive, five negative, while seven did not curve.

Fagopyrum esculentum, the plants having nearly ripe fruit, and treated as the foregoing species, gave twenty-four roots for experiment. After 38 hours, fourteen roots were positive, four were negative, and six were contorted.

Raphanus sativus, a month old, furnished twenty-eight roots for experiment. No curves appeared for the first 20 hours. After 50 hours of revolution of the basins, twenty-one roots had positive curves of 45 to 90°, three were contorted, and four were straight.

Again it appears here that the sensitiveness of roots to a stream of water is neither lost nor gained in increasing age of the plant. In the preceding chapter it was indicated that the secondary roots are less sensitive than the primary. The same conclusion is much more strongly indicated by the experiments just narrated. Yet one may not argue too strongly from these last experiments. Plants growing in crocks are probably not very vigorous, and tests have shown over and over again that lack of vigor inhibits irritable responses. To cite a single case, I may say that a crock of plants of *Helianthus annuus*, not in a vigorous condition, was kept for 60 hours over revolving water with two dozen roots immersed, and no curvatures appeared.

D. NATURE OF THE RHEOTROPIC STIMULUS.

The nature of the rheotropic stimulus has not been determined. In the paper read before the American Association for the Advancement of Science[13] in 1896, I suggested that the rheotropic stimulus was pressure. Juel (*l. c.*) has renewed the suggestion, but no one has offered any direct evidence. The physiological importance of rheotropism is difficult to perceive, and hence one suspects here a case where the mechanism developed in response to some biologically important stimulus is set in motion by some other stimulus, as an electric current throws a muscle into contraction.

[13] BOT. GAZ. **22**: 242. 1896.

If one considers the more common responses of roots, he will soon become convinced that rheotropism is none of these. Since the publication of Czapek's [14] hypothesis as to the means of the perception of the geotropic stimulus, one may even think of the possible connection of rheotropism with geotropism. If the direction of gravitation is perceived by the radial pressure of the layers of cells upon those more deeply lying, the pressure on one side of the root in flowing water would stimulate the gravitation pressure, and might call forth a pseudo-geotropic curve, the rheotropic curve. Since, however, it is almost certain that the gravitation stimulus is perceived by only the apical 1 to 2^{mm} of the root, and the rheotropic stimulus is perceived by 10 to 20^{mm} of the root, it is not probable that rheotropism is simulated geotropism.

Rheotropism is not necessarily connected with heliotropism; for several species, *e. g.*, *Raphanus sativus*, have been found rheotropic which are not heliotropic. Nor is rheotropism connected with hydrotropism; for, as demonstrated by Pfeffer,[15] in hydrotropism only the apical 1 to 2^{mm} of the root is sensitive. Rheotropism cannot be traumatropism; for in the former the response is the same when the stimulus is perceived by the tip of the root as by the part farther back. Aerotropism has been appealed to by many to account for various curvatures of roots in water. I have tested several species of plants with rheotropic roots for aerotropism, by bringing submerged chambers of air within a few millimeters of the side of root-tips which were several centimeters below the surface of water. The confined air was in most cases separated from the roots by parchment paper. In other cases there was no membrane intervening, the submerged chamber being tilted so as to hold the air, while the roots were brought within a few millimeters of the edge of the air-containing chamber. In none of these cases were the roots caused to deviate more than 5 to 10° from the vertical direction, and the

[14] Untersuchungen über Geotropismus. Jahrb. Wiss. Bot. **32**: 224.

[15] On this topic see Rothert, Flora **79**: 212. 1894; and Czapek, Jahrb. Wiss. Bot. **35**: 316.

majority of roots in any one preparation were unaffected. Rheotropism, therefore, is not aerotropism.

Lastly, we may ask what the probability is that rheotropism is response to pressure. On the one hand we know that the water current exerts one-sided pressure on the roots, and we are at a loss to perceive any other influence which the current may exert. On the other hand, a response of roots to pressure, either a positive or a negative response, has never been demonstrated. Sachs[16] thought he had found roots positively thigmotropic when stimulated on the elongating zone; but the curves produced were traumatic, as a forthcoming paper of mine will show. Darwin's[17] supposed negative thigmotropic curves of the root tip have been shown to be traumatropic by Wiesner[18] and Spalding.[19]

If the rheotropic curving is due to pressure, it might be thought that solid particles in the water stream might cause either an earlier or a greater response. Two experiments were tried with seedlings of *Helianthus annuus*, in one of which wheat flour was stirred into the water stream and in the other clay was used. In each case a control was set up with roots in water filtered through a Berkefeld filter. While the water was revolved the solid material was stirred up every half hour. In the first test the roots gave a readier response in the filtered water than in that containing the flour; in the second case, responses appeared at about the same time and the roots attained about the same angles in both basins.

There is no evidence to show that roots are sensitive to pressure, and until that is shown it is idle to speculate as to the relation of rheotropism and thigmotropism.

E. SUMMARY.

I. STATEMENT OF CHIEF RESULTS.

The foregoing pages narrate the results obtained in experiment with thirty-two species of plants. These thirty-two species

[16] Arbeit. aus. d. bot. Inst. Würz. 1: 437.

[17] Power of movement in plants, 1880, p. 129.

[18] Das Begwegungsvermögen der Pflanzen, 1881, p. 139.

[19] On the traumatropism of roots. Annals of Botany **8**: 423. 1894.

include all plants but two that have been tested by others for rheotropism, and twenty-one species that have never been experimented with before. In my own work and that of others, therefore, thirty-four species have been used. Of these, twenty have proved positively rheotropic, and fourteen have been found insensitive. *Rheotropism cannot therefore be said to be a general phenomenon.*

The foregoing experiments teach nothing more clearly than that sensitive species differ greatly in the degree of sensitiveness to a stimulating water current. As with almost any other irritable response, one may arrange species in a series according to their rheotropism. The twelve species of plants reported as rheotropic by Jönsson, Berg, and Juel should all be accounted as but feebly or moderately sensitive as compared with five *Cruciferae* and *Zea mays* (*everta* Sturt.) as reported in this paper.

The fourteen species found insensitive are distributed through nine families, and the twenty sensitive species through six families. Several species in a single family have been tested in the case of the *Gramineae* with five species in five genera, the *Leguminosae* with ten species in seven genera, the *Cruciferae* with six species in three genera, and the *Cucurbitaceae* with two species in two genera. All five species of the *Gramineae* are sensitive, five species of the *Leguminosae* are sensitive and five insensitive, five species of the *Cruciferae* are sensitive and one insensitive, and both species of the *Cucurbitaceae* are insensitive. Two or more species in each of five genera have been under experiment, and in each genus the species have been either all sensitive or all insensitive. *There is an indication therefore that the roots of genetically related plants behave alike toward a water current.*

On the other hand, of two varieties of *Lupinus albus* tested, one gave no response, while the other showed itself fairly responsive; and of the varieties of *Zea mays*, all the large fruited forms were but feebly affected, while the popcorn was very sensitive.

The four aquatic plants and the semi-aquatic *Nasturtium officinale* are none of them sensitive to the water stream. It is

hardly probable, therefore, that rheotropism stands in any biological relation to water plants.

Berg in his paper was unable to determine whether the velocity of water current had any effect on the response. Juel, working only with *Vicia sativa*, obtained only straight or negatively bent roots in velocities as high as 1800^{cm} per minute, while positive curves appeared in the majority of cases in velocities from 1.8 to 1800^{cm} per minute. The highest percentage and the strongest curves were found in velocities between the extremes named; the lower limiting velocity was not found. In my experiments data were obtained on the action of several species in varying velocities of water. *It has been shown that velocities above 1000^{cm} per minute give generally negative (mechanical) curves, that the optimum velocity lies between 100^{cm} and 500^{cm} per minute, and that velocities below 50^{cm} per minute bring fewer and slower responses with smaller angles.* The remarkable result was obtained of finding the main root of *Raphanus sativus* rheotropic in a velocity less than 1^{cm} per second, while the directive influence of a velocity of 2^{cm} per second was no longer obeyed by the main roots of *Brassica alba*. It should be remembered, however, that the character of the curve in these very weak currents differs greatly from that shown in optimum currents, the actual curves in the latter becoming mere positive inclinations in the former.

The latent period for rheotropism was stated by Berg to be for *Zea mays* one hour with the reading microscope; while that of *Vicia sativa* according to Juel is two hours. Table VII on p. 272 of this paper shows the shortest latent period obtained for eight species of plants. There it is seen that species differs greatly in time of response, though the latent period for all is relatively long compared with that for geotropism. Compared with the heliotropic response, the geotropic response of *Brassica alba* and *Helianthus annuus* is not much slower. The actual latent period for rheotropism has not, however, been determined by anybody for any plant. In the first place, the experiments have not been carried on in the optimum temperature for growth; and in the second place, all experiments, so far, have been inter-

fered with by geotropism. In my own study some experiments were made in which the effect of gravitation was sought to be eliminated by using the centrifuge revolving with vertical disk under water. The plan is wholly feasible, but in my work was not pursued far enough to give final results.

In the competition between geotropism and rheotropism, which comes into play from the method of experimentation, some roots attain only a small deviation from the vertical, some reach 45°, and some 90°, the last seeming to overcome their geotropism wholly. When the definitive angle is attained by a root, this angle is retained for an undetermined period. Only in the case of weak stimuli have roots been observed to lose their responsiveness to the water stream and to resume their vertical position while the water stream still continued.

The occurrence of the geotropic counter-curve is explained in assuming that the resultant position of equilibrium for roots in which geotropism and rheotropism are competing is different in the apical 2^{mm} from what it is in the part of the root farther back. This difference in position of equilibrium for the two parts of the root is due to the extent of both the sensitive and the motor zones. The first curve in ordinary geotropic bending being located, in roots of medium size, not more than 2^{mm} from the apex of the root, the apex bends down when rheotropism is carrying the root beyond the resultant position of equilibrium. The geotropic sensitiveness being confined to the apical 2^{mm}, the part farther back is, by the sinking of the sensory zone, released to some degree from its impulse to bend downward. As there is in the experiment a continuous rising of the part of the root posterior to the apical 2^{mm} as growth goes on, we must assume that the motor zones for geotropism and for rheotropism, in this kind of experiment, are in different parts of the root—the former being within 2^{mm} of the apex, and the latter three or more millimeters from the apex.

The present paper has given evidence for the rheotropic sensitiveness of at least 15^{mm} of the apex of the root. By means of fine jets of water directed against the apical millimeter of the

roots of *Helianthus annuus* and of *Brassica alba*, ten positive curves in a total of eighteen roots were obtained. The other eight roots all remained straight. The relatively small proportion of curves was doubtless due to the shortness of the period of the experiments and to the technical difficulties involved in the method. By shielding from the water stream by a glass tube the whole root of *Zea mays* (popcorn) except the apical 1.5 to 2^{mm}, fifteen positive curves and sixteen straight roots resulted. Unfortunately the periods of the experiments for this plant were only from 4 to 8 hours. Had they all extended to 12 hours there would doubtless have been a much larger proportion of curves. The absence of any negative curves, however, shows that the curves obtained were really rheotropic. The apical 0.5 to 1.5^{mm} of the root of *Raphanus sativus* exposed to the water stream by the same method as used with *Zea mays* (popcorn) gave thirty positive curves and nine straight roots in a total of thirty-nine seedlings. In two of these experiments there was never more than 1^{mm} of root tip exposed to the current, yet even in this case more than half the roots became positive. *It may be claimed, therefore, that the rheotropic sensitiveness of the very apex of the root has been demonstrated.*

That the root of *Vicia sativa* is rheotropically sensitive throughout its elongating zone was indicated, but not demonstrated by the experiments of Juel (*l. c.*). He employed too few seedlings, especially in the case in which 7 to 8^{mm} of the apex of the root were covered with collodion caps, where he used only six roots and obtained only two reliable curves. In my experiments forty-eight seedlings of *Raphanus sativus* had their apical 10^{mm} covered with glass tubes, and thirty-four gave positive response in a water stream. In another series with the same species, twenty-three roots had their apical 15^{mm} of the root covered, and ten gave positive curves. When, however, nineteen seedlings of Raphanus had 20^{mm} of the apex of their roots covered, only seven very weak positive curves appeared, while there were four weak negative curves, and eight straight roots. *It may be said, therefore, that the roots of Raphanus sativus are rheotropically sensitive for more than 15^{mm} of their apex*, but

scarcely, if at all, sensitive beyond 20^{mm} of their apex. In preceding pages it has been shown that *the rheotropic sensitiveness decreases proximally from the limit of the elongating zone*. Since the elongating zone in *Raphanus sativus* has been shown to extend less than 6^{mm} from the apex of the root, *we have in this plant, and probably in other rheotropic plants also, a sensory area ten or more millimeters distant from the limit of the elongating zone, and therefore a transmission of stimulus through a distance of twelve or more millimeters from tissue that has ceased to elongate*.

Rheotropism is not confined to the primary root. Berg (*l. c.*) states that he observed it in the secondary roots of eight species of plants, while it was absent in one species. My tests extended to four species. Putting Berg's results and mine together, eleven species with both primary and secondary roots have been tested for the rheotropism of secondary roots. Of these eleven species, eight have shown themselves positive in both primary and secondary roots, two have shown themselves neutral in both orders of roots, and one (*Tropaeolum majus*) was found sensitive in both orders by Berg, but feebly sensitive in the primary and neutral in the secondary roots by me. Berg makes no statement as to relative sensitiveness of primary and secondary roots. In my experiments the secondary roots of *Fagopyrum esculentum* were less sensitive than the primary, but the secondary and tertiary roots of *Zea mays* (yellow dent) were more sensitive than the primary. *One may conclude at least that the secondary roots are sensitive or insensitive according to the sensitiveness or insensitiveness of the primary root.*

All the experiments of former investigators of rheotropism have been carried on with seedlings. In my study the roots of older plants have been tested in five species. The seedlings of four of these species had proved themselves rheotropic, and the roots of the same species a month old were found rheotropic also. In the case of the fifth species neither the roots of the seedlings nor of the older plants were sensitive. *As far as the study has extended, therefore, it has been found that rheotropism is neither gained nor lost in the development of a plant from seedling to near maturity.*

As to the nature of the rheotropic stimulus, there is no direct evidence. I still incline to the notion of pressure, as expressed in my paper before the American Association for the Advancement of Science in 1896. As yet, however, no one has demonstrated in the roots of plants any kind of a response to pressure.

II. TABULATION OF SPECIES EMPLOYED AND THEIR RHEOTROPIC BEHAVIOR.

Family	Species	Rheotropic behavior
Gramineae	Zea mays L. Yellow dent	Feebly sensitive
	" " Sweet	Feebly sensitive
	" " Popcorn	Highly sensitive
	Triticum vulgare Vill	Feebly sensitive
	Hordeum vulgare L	Highly sensitive
	Secale cereale L.	Highly sensitive
	Avena sativa L	Highly sensitive
Hydrocharitaceae	Elodea canadensis Michx	Insensitive
Naiadaceae	Potamogeton perfoliatus L	Insensitive
Liliaceae	Allium cepa L. Bulb	Insensitive
	" " Seedlings	Insensitive
Ranunculaceae	Ranunculus aquatilis L	Insensitive
Cupuliferae	Quercus alba L	Insensitive
Cucurbitaceae	Cucurbita pepo L	Insensitive
	Citrullus vulgaris Schrad	Insensitive
Cruciferae	Brassica alba Boiss	Highly sensitive
	Brassica nigra Koch	Highly sensitive
	Brassica campestris L	Highly sensitive
	Brassica oleracea L	Highly sensitive
	Raphanus sativus L	Highly sensitive
	Nasturtium officinale R. Br.	Insensitive
Geraniaceae	Tropaeolum majus L	Feebly sensitive
Polygonaceae	Fagopyrum esculentum Moench	Highly sensitive
Euphorbiaceae	Ricinus communis L	Insensitive
Leguminosae	Vicia faba L	Feebly sensitive
	Vicia sativa L	Fairly sensitive
	Lupinus albus L	Fairly sensitive
	Phaseolus vulgaris L	Insensitive
	Phaseolus lunatus L	Insensitive
	Phaseolus multiflorus Willd	Insensitive
	Pisum sativum L	Fairly sensitive
	Glycine hispida Maxim	Insensitive
	Dolichos lablab L	Insensitive
	Lathyrus odoratus L	Fairly sensitive
Compositae	Helianthus annuus L	Fairly sensitive

In addition to ten of the species in the foregoing table, Berg tested *Lupinus luteus* L. and *Fagopyrum tataricum* Gaertn., both of which he found sensitive.

UNIVERSITY OF MICHIGAN,
Ann Arbor, Michigan.

PARTHENOGENESIS IN THALICTRUM PURPURASCENS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXV.

JAMES BERTRAM OVERTON.

(WITH PLATES XII–XIII)

INTRODUCTORY.

THE well known experiments of Loeb in inducing by artificial methods the segmentation of the unfertilized eggs of some of the lower animals, and the formation of embryos, suggested similar experiments with the eggs of plants. Experiments of like nature have been made upon lower plants, but the eggs of the higher plants do not lend themselves readily to experiment. Nevertheless, it was concluded to make the attempt with some angiosperm. It seemed best to select a dioecious plant, and one suspected of exhibiting parthenogenesis. The clue was furnished in a paper read by David F. Day at the Buffalo meeting of the American Association for the Advancement of Science in 1896. It was entitled "Parthenogenesis in *Thalictrum Fendleri*," and the following abstract was published in the Botanical Gazette (**22**: 241 S 1896):

> In 1883 a seedling of *T. Fendleri* was sent home from Colorado for cultivation. In late May it flowered and proved to be pistillate. About the last of August it presented abundant and good seed, although no staminate plants of any species of Thalictrum were in the neighborhood. The seeds were planted and yielded abundantly staminate and pistillate plants. Staminate plants have been artificially prevented from maturing flowers almost every year since. At least eight times in thirteen years the pistillate plants have produced good seed in abundance. Plants were sent to Meehan, Missouri Botanical Gardens, and Orpet of S. Lancaster, Mass., and all report in 1896 perfect seed from pistillate plants. This seems to be a clear case of parthenogenesis. *T. dioicum* does not show a similar habit.

This might have been a case of parthenogenesis or of vegetative apogamy, not to be determined without careful morpho-

logical study. In any event, it suggested a species for study, and the allied *T. purpurascens*, abundant in the vacant lots in Chicago, was selected.

The work was begun early in the summer of 1900 and carried on at the Hull Botanical Laboratory of the University of Chicago. Acknowledgments are due to Professor John M. Coulter for much suggestive advice during the prosecution of the work, and also to Dr. Charles J. Chamberlain and Dr. Burton E. Livingston for assistance in collection, technique, and interpretation. Mr. Andrew C. Moore, now of the University of South Carolina, also gave much assistance in collecting material.

METHODS.

A compound microscope was taken into the field in order to determine whether the flowers were pistillate or staminate. Only such plants as were found by this means to be pistillate were used. In fact, the flowers were all too young to be determined in any other way. A dozen such pistillate plants were isolated in the greenhouse of the laboratory, nine of which survived. The plants were numbered, and watered with solutions of various salts. This mode of treatment was kept up until after the time fertilization would have taken place normally and until the stigmas ceased to be receptive. Each week some of the developing flowers were killed in a one per cent. solution of chrom-acetic acid and kept in 70 per cent. alcohol for further study. In the autumn these plants were dried and their rootstocks preserved in pots over winter. These were forced about the first of April, and all produced abundant pistillate flowers long before those out of doors had blossomed. This made it certain that pollination did not occur, as these flowers were mature and their stigmas had ceased to be receptive long before those out of doors had even begun to bloom, much less to produce pollen.

Fifteen or sixteen other pistillate plants were chosen at the same time by the same means and transplanted into the garden of the laboratory. The inflorescences of these were securely covered or capped with paper bags so as to prevent pollination.

The flowers developed in these bags from the time the pistils had to be determined by means of the microscope until the seeds matured. Each week a head was removed, the flowers being preserved as above for future study.

All plants that survived under all the conditions, in the greenhouse, or in the garden, or as rootstocks, produced abundant and fully developed seeds. Of course in such a case it seemed unlikely that the treatment with the solutions produced the effect. Therefore the problem resolved itself into an investigation of the embryos, to determine whether or not there was parthenogenesis, the embryo developing from the unfertilized egg, or vegetative apogamy. Abundant and good material had been preserved, which it was hoped would show all stages required to answer this question. The material after fixing and killing was brought gradually into 70 per cent. alcohol and there kept until used. The xylol-paraffin method was used entirely, and sections were cut with a microtome from 5–15μ thick as the case required. Sections were stained with Delafield's haematoxylin and also with Flemming's safranin, gentian-violet, and orange method. All drawings were made with a Zeiss camera and a $\frac{1}{12}$ Bausch and Lomb oil immersion.

RESULTS.

It is not the purpose of this paper to describe the development of the megaspore in detail, for it differs in no way from that usual among angiosperms. In the very young ovule the archesporial cell is distinguishable (*fig.* 1, *a*), later enlarging (*fig.* 2), and dividing unequally to form the so-called tapetal cell (*fig.* 3, *t*) and the larger primary sporogenous cell (*fig.* 3, *s*). The tapetal cell may or may not divide further. *Fig.* 4 shows a division. The primary sporogenous cell gives rise to the usual row of four megaspores (*fig.* 5), the innermost spore of the tetrad functioning (*fig.* 5, *fm*).

The megaspore germinates in the usual way, enlarging at the expense of the surrounding cells until it occupies a large part of the nucellus (*fig*, 6), and the nuclear divisions resulting in the usual groups of nuclei at each extremity of the sac.

Fusion of the polar nuclei takes place immediately, and this seems to act as a stimulus for the rapid enlargement of the sac (*fig. 6, pp.*). The fusion nucleus also enlarges very rapidly and staining shows it to be rich in chromatin. It may lie near the oosphere, or in the center of the sac, or close to the antipodals (*figs. 7, 8, 11*). It is always surrounded by abundant cytoplasm, which is connected by strands to the mass about the egg and the antipodals, and often contains numerous nucleoli. It remains very large and active while the sac is enlarging to four or five times the size it had when the polar nuclei fused (*fig. 11*).

The synergids present the usual appearance. They are vacuolated at the lower end, with the nuclei above the vacuoles, the upper end presenting a striated appearance (*fig. 11 syn*).

The oosphere is not much longer and very often shorter than the synergids (*o* in *figs. 6, 7, 8, 11*), and is never very rich in stainable material, the nucleus taking only slightly the stain taken by the definitive nucleus very heavily. There is abundant cytoplasm surrounding the egg in all cases, with strands radiating to the mass about the definitive nucleus, as above mentioned. Although the egg is usually shorter than the synergids at the time of fusion of the polar nuclei (*figs. 6, 7, o*), after this fusion, while the sac is greatly enlarging in all directions (*fig. 11*) especially in length, the egg begins to reach down into the sac far below the synergids, becoming highly vacuolated and staining very feebly (*figs. 3, 7, 10, a, 11, v*), appearing to reach its fullest development just at the time the free endosperm nuclei become parietally placed.

One of the most notable features of the sac is the remarkably large size of the antipodal cells, which often reach almost to the center of the sac, their nuclei multiplying by fragmentation (*figs. 7, 8, 11*).

As before mentioned, the definitive nucleus is remarkably large, resting near the egg, or near the antipodals, but more frequently centrally placed in the sac. Free nuclear division takes place very rapidly, and in no instance did division of the egg take place before division of the endosperm had begun. This

free nuclear division is so rapid as to produce in a remarkably short time a great number of nuclei, during which the sac enlarges very rapidly in all directions. It may be well to note here that the first division of the egg takes place when the free nuclei become parietally placed, lining the whole sac. Coulter found in species of Ranunculus "occasional evidence of endosperm-formation before the fusion of gametes, and even before the entrance of the pollen-tube into the cavity of the sac." In my examination of normal material of *T. purpurascens* I have been unable to find any stages that show segmentation of the egg before the definitive nucleus divides, in all cases free nuclear division having begun before fertilization. In the material that I know to be parthenogenetic the free nuclear division began without any stimulus from fertilization, and always before the egg divides. Undoubtedly fertilization, when it takes place, may exert an influence upon the definitive nucleus, as it is known to do upon other adjacent structures, but it is not absolutely necessary to its division. The parietal placing of the free endosperm nuclei is followed by the formation of cell walls, and the endosperm gradually fills the cavity of the sac.

As described above, the egg becomes elongated far below the synergids, and there seems to be a great lack of stainable material in both nucleus and cytoplasm. In every case observed the cytoplasm of the sac was very dense about the egg, except the zone immediately in contact with it. This layer appears to be of a different consistency and stains very little, much resembling the zone of broken-down endosperm tissue so frequently found surrounding an embryo in the seed. It suggests that the egg is giving off an enzyme that digests the adjacent cytoplasm.

No atte npt was made to trace in detail the development of this embryo, as that was not the purpose of the work. Without fertilization the first division occurs, and is transverse (*fig. 12*) as usual. The next division is also transverse, and a row of three or four cells is formed, after which a longitudinal division takes place in the terminal cell, differentiating the embryo-proper from the suspensor. The persistence of the synergids is very

noticeable, and this might be expected, since no pollen tube has entered the sac to draw upon them for food supply. The synergids in the normal material were not evident in all cases after the embryo had begun to develop. After the first longitudinal division of the embryo, similar divisions may take place in the suspensor, resulting in a massive, rather short, much twisted, thick-walled suspensor (*fig. 15, su*). Finally, the parthenogenetic embryo becomes morphologically well developed, showing dermatogen, periblem, and plerome, exactly as in normal embryos. In fact no difference can be seen between the perfectly normal embryo and this parthenogenetically formed one (*fig. 16*). The endosperm continues to develop until it entirely fills the cavity of the sac and lies in a mass about the embryo. Abundant seed is produced by *T. purpurascens*, both from free and isolated pistillate plants. The percentage of seed produced in the parthenogenetic material is quite as great as under perfectly normal conditions in the field.

GENERAL DISCUSSION.

There have been described only two other cases of true parthenogenesis among spermatophytes. In 1898 Juel[1] described parthenogenesis in *Antennaria alpina*. No figures were given, and we have to depend upon his text for the facts. In 1876 Kerner[2] had noticed that plants of *A. alpina* were matured in the Botanical Garden at Innsbruck when no staminate flowers were present. It is the rule for plants of *A. alpina* to have only pistillate flowers, while staminate flowers are exceedingly rare, and are not necessary to the propagation of the species. The pollen grains are not fully developed, or very seldom so, even when there are staminate flowers present, being functionless according to Juel. Juel maintained that Kerner did not find parthenogenesis in the true sense of the word, but only seed-development without fertilization. A critical study of *A. dioica* showed that it behaved

[1] Parthenogenesis bei *Antennaria alpina*. Bot. Centralbl. **74**:369. 1898.

[2] Parthenogenesis einer angiospermen Pflanze. Sitzungsb. Acad. Wiss. Wien **74**:469. 1876.

normally, fertilization occurring and the embryo coming from a fertilized egg. In *A. alpina*, however, he found that the egg forms an embryo without fertilization. In this case the polar nuclei never fuse or even approach each other, dividing independently to form the endosperm, which is finally absorbed by the embryo. Juel explains the behavior of the polar nuclei on the ground that one of the polar nuclei and the egg have arisen through the same nuclear division, and as the egg nucleus is able to divide without fertilization, the polar nuclei can divide without fusion. Even if this explains the division of the upper polar nucleus, it does not apply to the lower one. Juel did not follow the chromosome reduction at that time, but later investigated it in *A. alpina*. He found[3] that tetrad formation does not take place, while in *A. dioica* there is the usual row of four. Juel concludes that there is no reduction in *Antennaria alpina*, so that the nuclei of the parthenogenetic embryo contain the normal number of chromosomes.

In 1895 Murbeck[4] suggested that certain species of Alchemilla are parthenogenetic. During the summers of 1892 and 1893 he observed in the neighborhood of Stockholm a form of Alchemilla which seemed to be intermediate between two forms that grew in the same locality. In order to determine whether the intermediate form was a hybrid, he made a comparative study of the reproductive power, and later of the formation of pollen. In all three forms he found the pollen impotent, and yet all set seed. Two other forms, growing in the Royal Botanical Garden of the Academy of Science of Stockholm, behaved likewise. Material was also collected from different parts of Europe in 1894 and 1895. Murbeck found that *A. alpina*, *A. sericata*, *A. pubescens*, and *A. vestita* produced no pollen whatever; that *A. acutangula*, *A. subcrenata*, and *A. alpestris* sometimes developed pollen, but the amount was very much out of proportion to the number of seeds produced. Of the great number of species

[3] Botaniska Notiser 102. 1900.

[4] Skandinaviska former af Alchemilla vulgaris. Botaniska Notiser 265 (Fussnote). 1895.

examined only the oriental species *A. speciosa* showed normal pollen. He came to the conclusion, after mixing the plants and finding no variations in the species, that the pollen sparingly produced by some forms had no fertilizing power. These results he published in 1897,[5] with the statement that he hoped later to discover whether there is actual parthenogenesis or whether the embryo arises from the nucellar tissue. With this purpose in view, Murbeck examined numerous species of the section EUALCHEMILLA, but his important results are mainly derived from *A. alpina*. He has traced every stage of development from the archesporial cell to the formation of the embryo, and published his results in 1901.[6] He found a central mass of archesporial cells, and that the numerous primary sporogenous cells may each give rise to a row of three or four megaspores, one or all of which may give rise to embryo sacs. In regard to chromosome reduction, he observed in a pollen mother-cell of *A. arvensis* that the reduction number was 16, but he claims that in parthenogenetic species there is no reduction of chromosomes. He shows that there is no direct relation between endosperm-formation and embryo-formation. A noticeable fact is that before the egg divides the whole egg-apparatus stretches far into the sac, and then division takes place without fertilization, a perfect embryo being developed. The first division takes place while the flower is still in developmental stages. Murbeck also found two embryos in a single sac, one developed from the egg and the other from a synergid.

The two cases described by Juel and Murbeck, and *Thalictrum purpurascens*, described in this paper, are the only cases of true parthenogenesis thus far recorded among seed-plants, though of course the phenomenon is common enough among certain lower plants. The so-called cases of parthenogenesis among seed-plants, as *Coelobogyne ilicifolia*, *Mercurialis annua*,

[5] Om vegetativ embryobilding hos flertalet Alchemillor och den förklaring öfver formbeständigheten inom slägtet som densamma innebär. Botaniska Notiser 273. 1897.

[6] Parthenogenetische Embryobilding in der Gattung Alchemilla. Lunds Universitets Årsskrift **36** : 1–40. *6 pls.* 1901.

etc., were long ago shown by Strasburger[7] to be cases of vegetative apogamy.

In *Balanophoræ elongata* Treub[8] has shown that there is no fertilization, but that a "pseud-embryo" is developed apogamously from the endosperm. We see no reason why this whole "pseud-embryo" structure with the endosperm in which it develops may not be considered an embryo developed apogamously from the micropylar polar nucleus, which later organizes a growing point as does a normal embryo. Lotsy[9] found exactly the same state of affairs in *Balanophora globosa*, a species with no staminate flowers. In the case of *Rhopalocnemis phalloidès*, which Lotsy[10] also recently investigated, no seeds are ever produced. He could not discover a pollen tube, nor could he induce pollen tubes to develop by artificial pollination. In a few cases he secured some seeds, but was certain the embryos had developed from the eggs, probably after fertilization.

It is shown that an embryo may be produced from any cell of the embryo sac, and in this sense they may all be regarded as potential eggs. But since the same fact is true of cells of the nucellus, the statement has little significance. Experimental work done within the last five or six years upon the eggs of marine animals has thrown some light upon the causes of the segmentation of unfertilized eggs. Mathews[11] showed that the unfertilized eggs of star-fish could be made to extrude polar bodies by violent shaking. Morgan[12] found that eggs placed in sea water of a higher osmotic pressure than normal sea water divided upon being returned to the latter. Mead[13] showed that

[7] Ueber Polyembryonie. Jenaisch. Zeitschr. Naturwiss. **12** : 659. 1878.

[8] L'organe femelle et l'apogamie du *Balanophora elongata*. Ann. Jard. Bot. Buitenzorg **15** : 1–22. 1898.

[9] Balanophora globoso. Ann. Jard. Bot. Buitenzorg **16** : 26–29. 1899.

[10] Rhopalocnemis phalloides Jungh., etc. Ann. Jard. Bot. Buitenzorg II. **2**: 73–101. 1900.

[11] Anat. Anz. **9**: 150. 1894.

[12] Archiv. für Entwicklungs. mechanik der Organismus **8** : 448. 1899.

[13] Lectures at Woods Hole. 1898.

eggs of Chaetopterus could be made to divide by placing them in sea water to which KCl had been added. Morgan[14] confirmed the results obtained by Hertwig as to the action of strychnin sulfate. He expressed the opinion that eggs are in a state of unstable equilibrium, and would react to various stimuli by division just as other cells would react in other ways to the same stimuli. Loeb[15] found that exposure of eggs of Arbacia for a short period to sea water to which alkali or acid had been added induced cell division. He has arrived at certain conclusions by further experiments upon the unfertilized eggs of echinoderms.[16] He has shown that such eggs can be made to develop into normal embryonic forms through a certain increase in the osmotic pressure, produced either by electrolytes or non-electrolytes. He suggests the probability that parthenogenetic development is caused by loss of a certain amount of water from the egg. Mathews[17] found that karyokinetic divisions in the eggs of Arbacia could be induced by the lack of oxygen, by heat, by exposure to ether, alcohol, and chloroform. Loeb[18] also produced artificial parthenogenesis in eggs of other animals than echinoderms by increasing the osmotic pressure, as Chaetopterus, etc. His experiments have convinced him that the essential feature in increasing the osmotic pressure of the surrounding medium is a loss of water on the part of the egg. He also states that if we assume the spermatozoön starts the development of the egg in the same way as in the case of artificial parthenogenesis, it must follow that it possesses more salts of a higher osmotic pressure than the egg. He has also suggested that the spermatozoön may bring about the same condition in the egg as is produced by loss of water.

These experiments suggest an explanation of parthenogenesis as observed in Thalictrum. The egg is invested by a dense sheath of cytoplasm, and that there is some reaction between

[14] Science N. S. 2: 176. 1899. [15] Jour. Phys. 3: 447. 1899.

[16] Further experiments on artificial parthenogenesis and the nature of the process of fertilization. Jour. Phys. 4: 178. 1900.

[17] Jour. Phys. 4: 341. 1900. [18] Science N. S. 2: 70. 1900.

the two is evidenced by the change in the structure of the cytoplasmic layer immediately in contact with the egg. Whether or not the egg excretes an enzyme that digests the cytoplasm is a matter of detail. The fact remains that physical changes are evident in the cytoplasm in contact with the egg, which then divides. Such changes may well vary the osmotic pressure within the egg, and lead to nuclear division as shown by the experiments referred to above.

While *Thalictrum purpurascens* is parthenogenetic under artificial conditions, parthenogenesis also takes place in plants grown under perfectly natural conditions if pollination be prevented, as is shown by plants setting seed in the gardens when the flowers are covered with paper bags. All such plants showed quite as many seeds per plant as those which had been fertilized and grew in the field. Many flowers were cut from natural specimens in order to compare them with the parthenogenetic material. In many cases a pollen tube could be detected, but in far the greater number no such tube or any evidence of a tube having been present could be seen. One can tell by even a casual inspection of the micropyle whether a tube has been present or not. I am led to conclude that many seeds are produced parthenogenetically under normal conditions if for any reason fertilization fails. So far as I could determine, there seems to be no real necessity for pollination in order to propagate the species. The plant is getting towards the habit of complete parthenogenesis, when pollen will become impotent, a condition apparently attained by *Antennaria alpina* and several species of Alchemilla. Even though the number of recorded parthenogenetic genera among dicotyledons be so small, the genera are rather widely distributed. It would seem as if parthenogenesis must be of much more common occurrence among angiosperms than is at present known.

SUMMARY.

1. The development and germination of the megaspore is that usually found among angiosperms.

2. Fusion of the polar nuclei is early, always before fertili-

zation in normal material, and before the division of the egg in parthenogenetic material.

3. Fertilization is not necessary to embryo-development or to endosperm-development.

4. Embryos were produced parthenogenetically under all conditions, and normal material showed the phenomenon to be general in nature.

5. The cytoplasm of the early stages of the sac is closely packed about the egg. Later the egg becomes surrounded by an area much resembling a vacuole, which may affect the osmotic pressure and indicate a withdrawal of water, causing the oosphere to divide.

6. The development of the embryo in parthenogenetic material is the same as found in normal material.

7. Parthenogenesis is becoming fixed in Thalictrum.

ILLINOIS COLLEGE,
Jacksonville, Ill.

EXPLANATION OF PLATES XII AND XIII.

FIG. 1. Section of young ovule showing archesporial cell (*a*).

FIG. 2. The same, showing enlarging archesporial cell (*a*).

FIG. 3. Section of young ovule with integument forming, showing tapetal cell (*t*) and primary sporogenous cell (*s*).

FIG. 4. Anticlinal division of tapetal cell (*t*); the nucleus of the primary sporogenous cell also dividing.

FIG. 5. Young nucellus, showing tapetal cell (*t*), the three functionless megaspores (*m*), and the functional megaspore (*fm*).

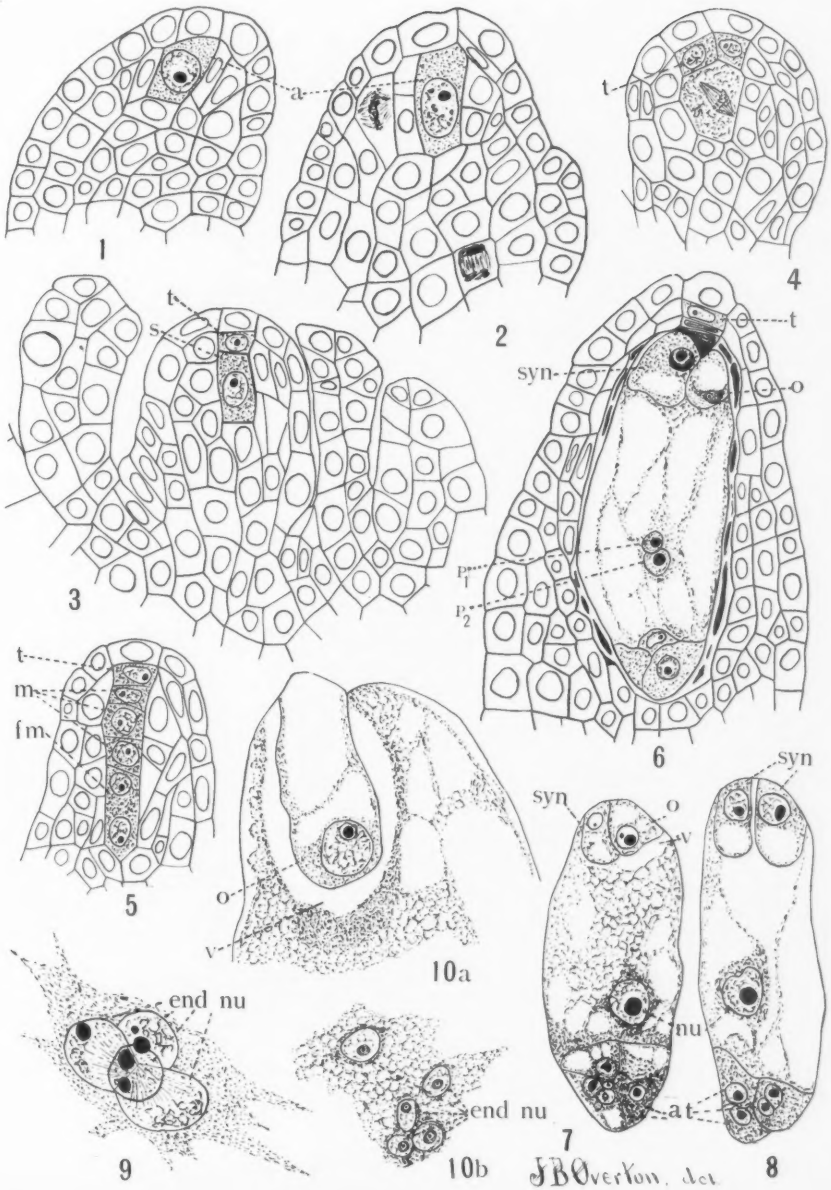
FIG. 6. Young embryo-sac; *syn*, synergid; *o*, oosphere; *t*, tapetal cell, with the three functionless megaspores crowded between it and the embryo-sac; P_1 and P_2, upper and lower polar nuclei fusing.

FIG. 7. Young embryo-sac immediately after fusion of polar nuclei; *o*, oosphere; *v*, area or vacuole about the oosphere; *syn*, synergid; *nu*, definitive nucleus; *at*, antipodals.

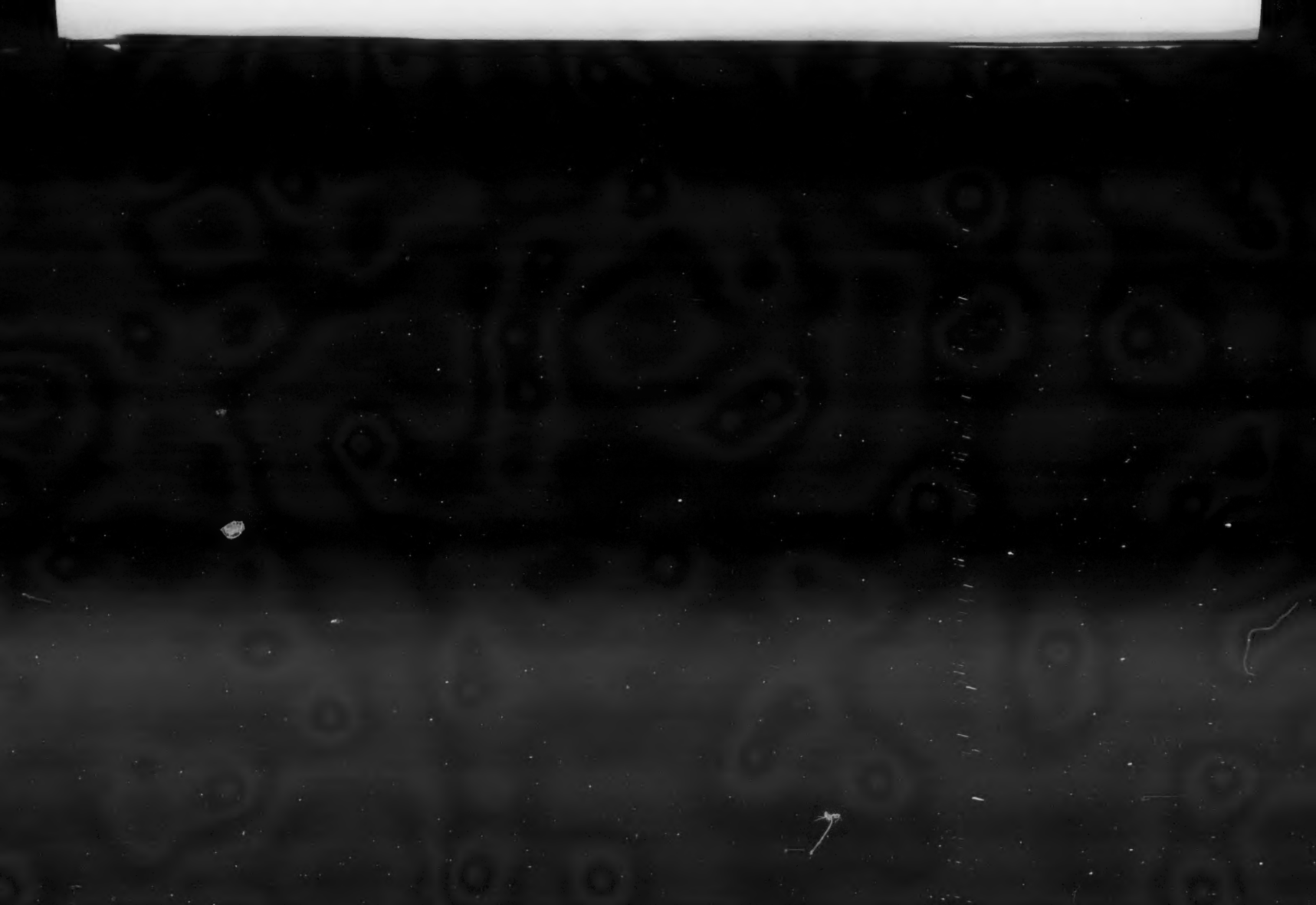
FIG. 8. Same as *fig.* 7, but showing both synergids (*syn*) without the oosphere.

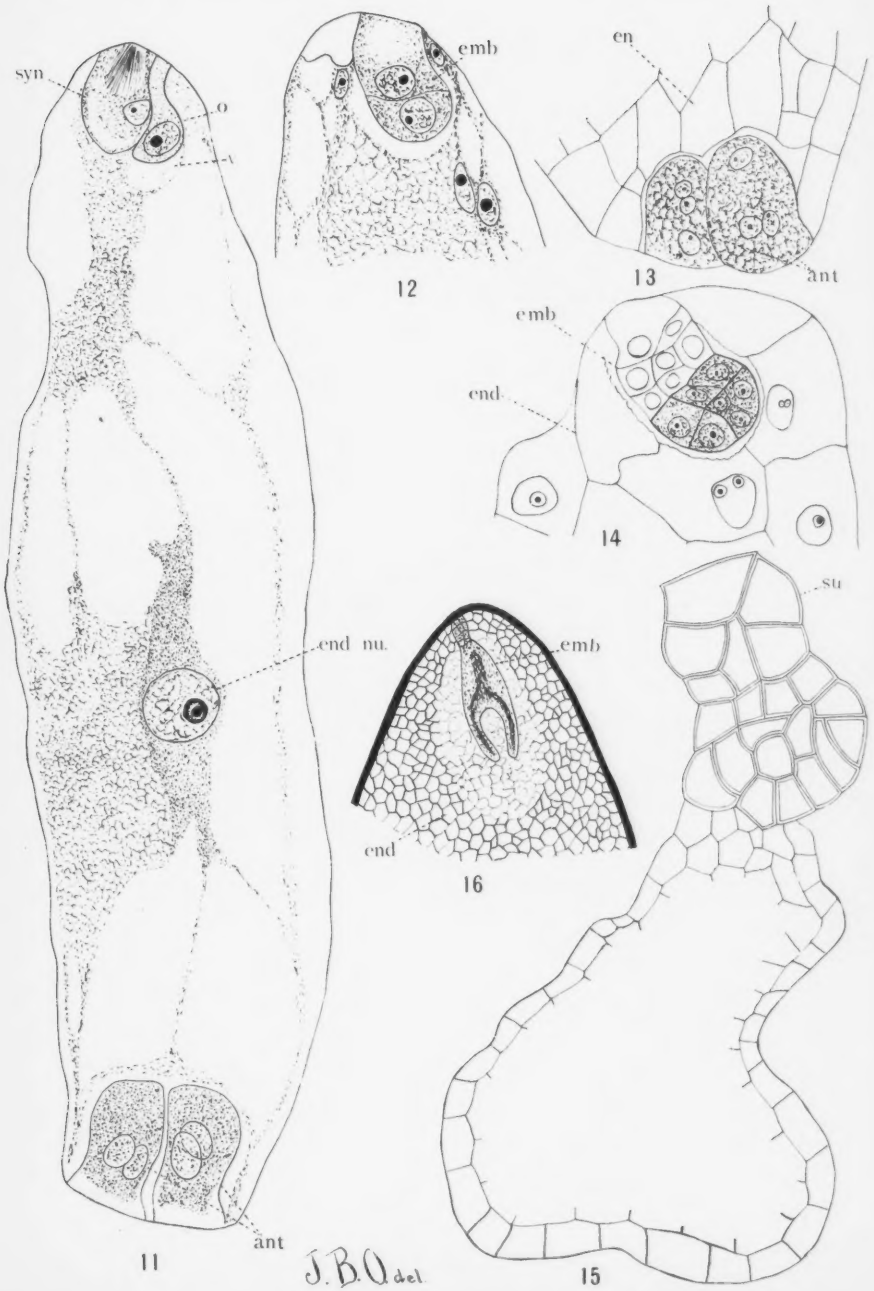
FIG. 9. A group of endosperm nuclei resulting from the first divisions of the definitive nucleus.

FIG. 10*a*. The oosphere (*o*) beginning to extend into the sac, with the vacuole (*v*) surrounding it.



OVERTON on THALICTRUM





OVERTON on THALICTRUM

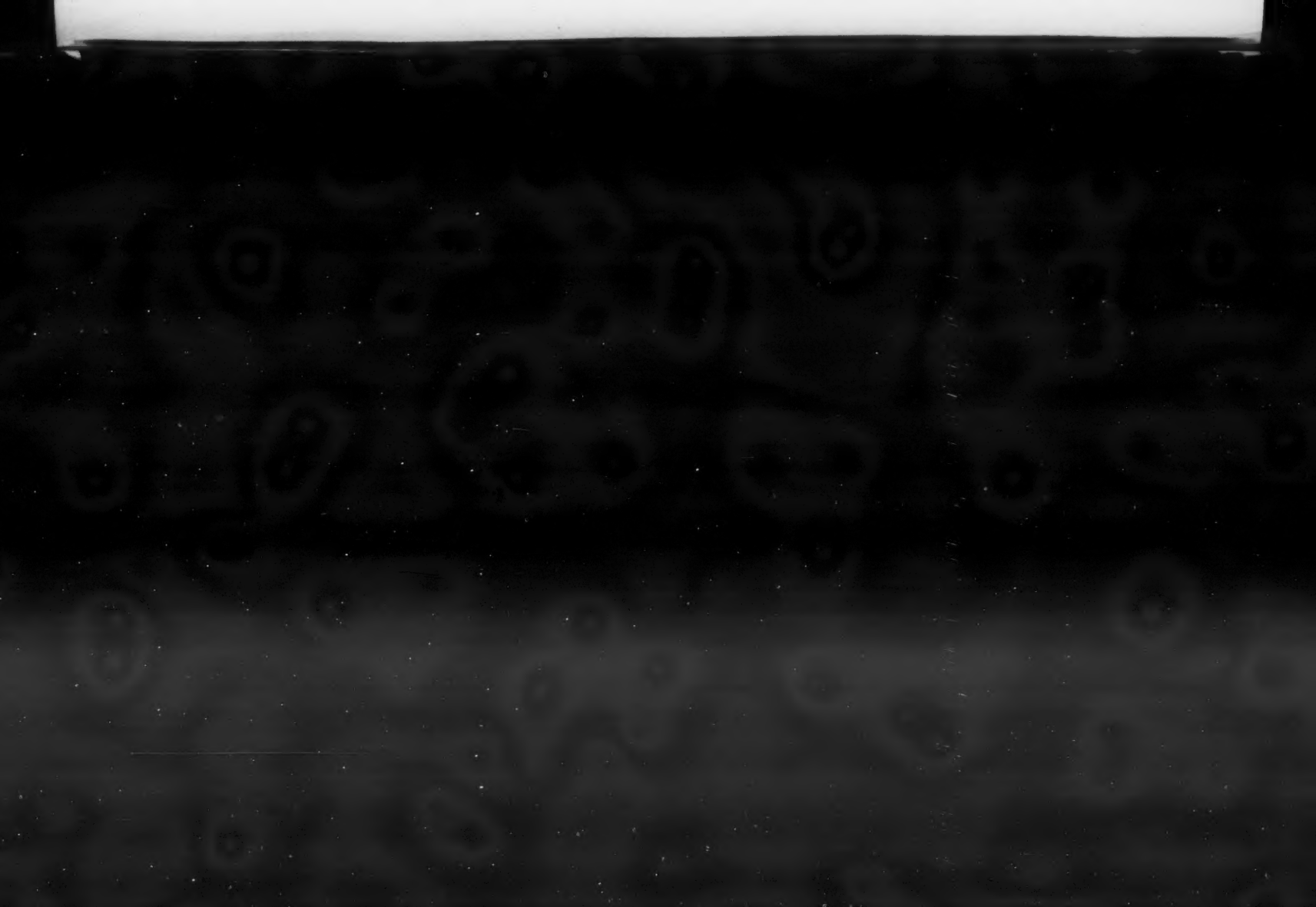


FIG. 10 *b*. A group of free endosperm nuclei from same sac, showing free endosperm nuclei before egg divides.

FIG. 11. Embryo sac just before the division of the oosphere; *end nu*, large and active definitive nucleus; *syn*, synergid; *o*, oosphere before elongation into the sac; *v*, vacuole forming about the oosphere; *ant*, large multinucleate antipodals.

FIG. 12. Two-celled parthenogenetic embryo (*emb*) with the vacuole about it; a few free endosperm nuclei are seen scattered in the cytoplasm of the sac.

FIG. 13. Antipodals (*ant*) still present when the embryo sac is entirely filled with endosperm cells (*em*).

FIG. 14. A young parthenogenetic embryo (*emb*) at end of suspensor, and surrounded by endosperm cells (*end*).

FIG. 15. A still more advanced parthenogenetic embryo, showing the thick-walled twisted suspensor (*su*).

FIG. 16. Diagrammatic sketch showing general relation of the parthenogenetic embryo (*emb*) to the endosperm (*end*) in the seed.

BRIEFER ARTICLES.

SUBTERRANEAN PLANTS OF EPIPHEGUS.

(WITH ONE FIGURE)

HAVING need of *Epiphegus virginiana* in late October, 1900, I sought a piece of beech woods in Holbrook, Massachusetts, where I found the plant growing abundantly in rich, deep humus. It was past the flowering time of this species in the main, but the warm season that year was unusually protracted, and numerous short shoots were being produced from the swollen stem bases, upon which I found flowers and fruit in all stages of development. The flowers borne by these late branches are very small. They are all cleistogamous and invariably give rise to capsules filled with fertile seed.

Occasionally these secondary shoots were observed to be flowering somewhat below the surface of the ground. This fact led to further exploration, and on turning up the mold I found many shoots that for one reason or another had never escaped from the soil. They were as productive of fruit and seed as the aerial branches. Finally, I brought to light a number of whole plants that had come to maturity below the surface. They were buried one or two inches deep, and were dwarf specimens, an inch or less in height. They bore several fruits containing good seed. A life-size figure of two of these plants is given herewith.

Whether this variation is simply physiological and due to tardy germination or lack of nourishment, as seems probable, or is constitutional and inheritable, the case offers an interesting example of a phanerogam leading its existence, and indeed completing its entire cycle of life, underground.—R. G. LEAVITT, *The Ames Botanical Laboratory, North Easton, Massachusetts.*

NOTES OF TRAVEL. VIII.

AMERICAN AUTUMN FOLIAGE IN EUROPE.

AS I TRAVEL through the forests of Arkansas and feast my eyes upon the splendor of their autumn foliage, which is second in beauty

only to such regions as the Berkshire hills, I am reminded of a little discovery I made last October in Bavaria. In visiting the large nursery of the brewing institute of Weihenstephan at Freising near Munich, my attention was attracted by several dashes of bright red color among the generally somber browns and yellows of the autumn foliage. These flashes of color were quite remarkable, even from the distant hill where the institute stands. Upon inquiry I learned that this bright-colored foliage was borne by American and Japanese trees or shrubs, and that the brightest of all was our common American *Quercus rubra*, whose leaves were as deeply colored as I have ever seen them in America. Inspector Steinbock remarked, when I expressed my surprise at their color, that there were in the park near Munich several good-sized trees of the swamp maple (*Acer dasycarpum*) whose leaves regularly colored up in the autumn the brightest wine red. I visited these trees and was gratified to find them of the same dark red which we are accustomed to associate with this species in America. The Japanese species which was so brightly colored at the brewing institute was a species of Berberis, I believe, according to Mr. Steinbock, and its narrow leaves were a dark crimson.

So much has been said about the peculiarities of American and Japanese climate as a cause for the brilliant autumn foliage characteristic of these countries, that I fear we have left out of account the consideration of the species themselves. The matter may have been thoroughly discussed in the horticultural literature, but I know of no experiments bearing on the question. If the European oaks when grown in America show fine or quite different colorings from what they do at home, there the effect of climate must be accepted; but the fact just pointed out, that American oaks and maples color up brilliantly in Europe, points to a possible difference of species.

That the local climatic conditions about Munich are not responsible for the color I discovered on mentioning the matter to Mr. Schattel, of the firm of Vilmorin & Company in Paris. He assured me that in the large arboretum of M. Maurice de Vilmorin the same remarkable fact had been observed, and that certain of the American oaks and maples there were most brilliantly colored in autumn. One cannot fail to be struck in such wonderful parks as those of Compeign in France, the Thiergarten of Potsdam in Prussia, or the royal palace grounds in Munich, by the lack of those gay colors in the landscape that give to our autumn so large a share of its peculiar charm. A few

judiciously planted American oaks or maples in these parks would give to the effect just those touches of color that to an American eye seem lacking to make perfect an autumn afternoon stroll.

There is a large field for the study of autumn foliage in Europe and in this country. Individual peculiarities ought to be studied and trees that can be propagated asexually chosen from the thousands of seedlings in the parks. The physiological conditions which produce these colorations will be most interesting, and the effects of hybridization of highly coloring species may be something phenomenal. With the growing passion for ornamentals this feature cannot fail long to attract serious attention, and it would be an easy thing to carry on some international experiments, introducing into Europe quantities of our gorgeously coloring species.—DAVID G. FAIRCHILD, *Department of Agriculture, Washington, D. C.*

A NEW HELIOTROPIUM.

THE cosmopolitan *Heliotropium curassavicum* is supposed to be sufficiently well known, and the idea that the name may at present cover more than one species does not seem to be entertained. However, when I saw the plant passing as *H. curassavicum* in southern California, last summer, I was strongly impressed with the idea that it was quite distinct from that of southern New Mexico (Mesilla valley) and northern Mexico (Juarez in Chihuahua), which had been familiar to me for some years past. The latter plant is lower and less robust, with white flowers, which are visited at Juarez by a peculiar bee of the genus Perdita, a strong indication that the plant is really a native of the region.

The Californian plant I described from fresh material gathered at San Pedro in July, as follows: Spreading, about 20^{cm} high, robust, main stems 6^{mm} in diameter, bluish-green; leaves spatulate, the largest about 53^{mm} long and 20 broad; average leaves 27^{mm} long and 9 broad; larger leaves about 1^{mm} thick, smaller 0.5^{mm}. Flowers arranged as in *H. curassavicum;* flowering spikes usually in threes, about 25^{mm} long, elongating fruit to 60^{mm} or more; flowers 7^{mm} diameter, varying in the same spike from 5 to 6-lobed corolla; corolla white, throat deep purple or yellow (both colors on same spike); calyx-lobes lanceolate, equaling the tube of the corolla; corolla more or less purple outside, so that the buds appear purple.

The yellow-eyed flowers are the freshest; probably they later become purple-eyed. This plant goes south along the seacoast, at least to San Diego county. I consulted a number of floras of different parts of the world, and found that the flower of *H. curassavicum* was almost universally considered to be white. Unfortunately, in drying the plant turns black, and I have never been able to prepare really satisfactory herbarium specimens. It may be on account of this difficulty that the several species (if such there are) have not been discriminated. If botanists resident where presumed *H. curassavicum* grows will carefully note the characters of the living plants, perhaps we may in time reach the solution of the matter.

Since writing the above note I have obtained fresh material of the New Mexico species at Albuquerque, still in flower December 3, 1901. Renewed comparisons make it evident that this inland form requires a distinctive name, as follows:

Heliotropium xerophilum, n. sp.— Flowers 3.5^{mm} in diameter; corolla 5-lobed, white (not turning violet), tinged with yellow within; lobes small, rounded; flowering spikes only about 20^{mm} long; calyx lobes narrow, pointed; fruit globular, 4-lobed, with distinct sutures, lobes rounded; leaves obtuse-lanceolate, about 30^{mm} long and 7 broad.—T. D. A. COCKERELL, *East Las Vegas, New Mexico.*

CURRENT LITERATURE.

BOOK REVIEWS.

The physiology of plants.

Another part of the new edition of Pfeffer's text-book of plant physiology[1] has recently been published. This is the first part of Vol. II, which deals with energy exchanges in the plant. The first volume appeared in 1897.[2] This part embraces ten chapters, headed as follows: I. Movement of growth; II. Mechanism of growth; III. Growth and cell division; IV. Elasticity and cohesion in the plant body; V. Tissue tensions; VI. Influence of external conditions upon growth; VII. Internal causes of specific configuration; VIII. Variation and heredity; IX. Rhythm in the processes of growth; and X. Power of resistance to extreme conditions. The subject-matter has been largely rewritten, so that the present edition is quite distinct from the former one. The treatment is divided into topics which are numbered consecutively throughout the volume, regardless of chapters.

Each chapter contains a full and critical treatment of the present condition of the subject, together with a historical résumé of the contributions which have been most important in bringing our knowledge to its present state. The literature is pretty well brought up to the date of publication, and citations by footnotes are very numerous. The practical value of these citations would have been much enhanced had the use of the sign *l. c.* been avoided by an occasional repetition, and had a more general uniformity in the form of citation been observed; here and there appears even that *bête noire* of the student of scientific literature, a reference by page to a repaged separate. Besides this comprehensive treatment of our present knowledge, a discussion of the subject from the theoretical side is also presented. As is quite usual with this author, the discussion often goes so far as to point out not only promising lines for future research, but also the possible and probable results of such work.

If there can be noted in the style of the author any change since the appearance of the previous edition, it is in the direction of greater clearness and directness of statement. The curiously involved sentences, which have

[1] PFEFFER, W., Pflanzenphysiologie, ein Handbuch der Lehre von Stoffwechsel und Kraftwechsel in der Pflanze. Zweite völlig umgearbeitete Auflage. II Band: Kraftwechsel. 1 Hälfte. 8vo, pp. 1–353. *figs. 31.* Leipzig: Wilhelm Engelmann. 1901.

[2] See review in BOT. GAZ. **25**: 132. 1898.

made Pfeffer one of the most difficult writers for the foreign student, are still in evidence, but, if we judge rightly, not so emphatically in evidence as heretofore. A tendency to avoid terms which serve only to cover up our ignorance, and an attitude of mind which seeks for explanations of physiological phenomena on physical and chemical grounds, is somewhat more pronounced here than in the previous edition. A feeling of admiration and wonder must be aroused in every reader of this volume by the exceedingly broad and familiar grasp of the whole subject that is shown by the author. There seems to be no corner of the realm of physiology into which the acuteness of Dr. Pfeffer's intellect has not allowed him to find his way. This seems to us to be the strongest among the many good qualities possessed by the book, but coupled with it — perhaps necessitated by it — is a quality which is surely destined to cause much dissatisfaction and weariness of the flesh on the part of the student. We refer to the numerous cross references found on nearly every page. To get the author's whole view of any subject one must at length read a good part of the volume.

English readers will hope for the speedy appearance of a translation of this book into their own tongue, for it will surely be from now on the standard reference on the physiology of growth and irritability. All students of this subject will await with impatience the publication of the rest of the volume. — BURTON E. LIVINGSTON.

Enzymes and their applications.

IN 1898 Dr. Jean Effront,[3] of Brussels, published the first volume of an important work upon enzymes and their industrial applications. That work has recently been translated by Professor Prescott, of the Massachusetts Institute of Technology, with the desire "to make available in English the valuable material of the original French work." This volume is devoted to the enzymes which act upon carbohydrates, and to theoxidases. In addition to these, however, it includes a discussion of the glucoside and glyceride enzymes. As only one chapter is devoted to them and one to the oxidases, it will be seen that the greater part of the work is devoted to the carbohydrate enzymes.

Throughout the book the emphasis upon the industrial relations of these substances is very strong. For example, chapter 11 is devoted to the discussion of chemical transformations which accompany germination, the methods of malting, sorting, steeping, germination, and brewing. Chapter 12 is devoted to the rôle of amylase in the brewery; chapter 13 to the manufacture of maltase; chapter 14 to the fermentations which occur in bread

[3] EFFRONT, JEAN, Enzymes and their applications. Translated by Samuel C. Prescott. Vol. I: The enzymes of the carbohydrates. The oxidases. pp. xi + 322. New York: John Wiley & Son. London: Chapman & Hall. 1902. $3.00.

making; and chapter 15 to the rôle of amylase in the distillery. Much attention is also devoted to methods of determining the activity of enzymes, to which Effront himself has contributed greatly, as indeed he has to the whole subject.

Three enzymes are considered in great detail, namely, sucrase (invertase), amylase (diastase), and maltase. The most important industrial applications of maltase seem to be in the manufacture of various oriental beverages.

In several inductory chapters the author discusses the general properties, the mode of action, and the individuality of enzymes. For the general reader or the physiologist these chapters will be found the most useful. The translator adheres to the author's use of the term diastase in its general sense as a synonym of enzyme. In view of the very wide application of the word diastase to a particular group of enzymes this usage may lead to confusion. In general the translation is satisfactory, though the choice of words is not always happy, and the paragraphing might have been greatly improved upon. At the close of each chapter there is a bibliography. The incompleteness of the citations and the diverse forms used will be a source of annoyance to anyone attempting to look up references. The translator could have done good service to English readers by adopting some consistent plan of citation and supplementing the author's bibliographical work.

This book will be certain of comparison with Green's recent work on the *Soluble ferments and fermentation*. The two are written from a wholly different standpoint; in Green's work the industrial applications are only incidentally touched upon, but in those portions where comparison is possible it will hardly be to the advantage of the Effront book. The latter produces an impression of fragmentariness and incompleteness, and there is a lack of finish, all of which leave the reader without a clear-cut impression. This is no doubt due in part to the incompleteness of the subject, for in reality much remains to be discovered regarding these bodies, but part of the result named must be ascribed to the work of the author and translator.

The book, however, will be extremely useful to schools and individuals concerned with the industrial processes of baking, malting, brewing, distilling, etc., in which fermentation plays so important a part.—C. R. BARNES.

Outlines of botany.[4]

MR. LEAVITT has prepared, at the request of the botanical department of Harvard Universty, a text-book of botany for secondary schools, based upon and evidently intended to replace Gray's *Lessons in botany*, which, even in its

[4] LEAVITT, ROBERT GREENLEAF, Outlines of botany, for high-school laboratory and class room, based on Gray's *Lessons in botany*. Prepared at the request of the botanical department of Harvard University. 8vo. pp. 272. *figs.* 383. New York: American Book Company. 1901. Also, combined with *Field, forest and garden botany*.

revised form, is growing less and less acceptable. An endeavor has been made, according to the author's statement, to provide for the "many schools which, having outgrown certain now antiquated methods of teaching botany, find the best of the more recent text-books too difficult and comprehensive for practical use in an elementary course. . . . . The descriptive text follows in the main the sequence of topics of Gray's *Lessons in botany*, and certain parts of that book have been retained. . . . . The writer has felt free to adopt the phraseology of Dr. Gray wherever desired, without quotation marks. . . . . But the greater part of the descriptive text throughout is new, the chapters on cryptogams and on physiology being entirely so."

Mr. Leavitt's own part of the book is fresh, well chosen, and clear, with hardly more than that seemingly irreducible minimum of error to be found in all elementary books. Especially noticeable is the position and character of the laboratory directions, which precede the text on each topic. Besides the section on cryptogams, of fifty-five pages, eighteen pages are devoted to the minute anatomy of flowering plants, and twenty-one to a "brief outline of vegetable physiology." Many of the illustrations are from the admirable drawings made for the *Lessons* and *Structural botany*, and a large number of new ones are introduced, which are both well chosen and well executed.

It will be clear, however, to anyone who considers the laboratory directions that there is much more work laid out, especially in the sections on "cryptogams," than can possibly be accomplished, even in a year of work. Moreover, the laboratory directions for "cryptogams" demand an unusually large amount of material and a thoroughly prepared teacher—the very things which have caused "the best of the more recent text-books to be characterized as too difficult and comprehensive for practical use in an elementary course." That is to say, the teacher must be adequately trained in botany and capable of selecting even from Mr. Leavitt's book. Neither the ignorant nor the slave will be able to use it.

In the absence of any discussion of alternation of generations until the ferns are reached, the relation of the two phases of the liverworts and mosses is left somewhat obscure. Heterospory and the seed habit are touched rather vaguely; indeed, when undertaking to elucidate the "relationship of cryptogams and phanerogams" suppositions are proposed regarding Selaginella which need not he imagined, because they are facts.

Throughout the book the author has retained a great deal of the formal Goethean morphology which characterized the *Lessons* and *Structural botany*. Another survival is to be seen in the maintenance of the division of plants into flowering and flowerless. The author has dropped into smaller type many of the sections which merely define the technical descriptive terms. The chapter treating of the flower, however, is still hardly more than an extended glossary.

We hazard a guess that the demands of the botanical department of Harvard University are more responsible for these features than the judgment of the author. It seems a pity to attempt to galvanize the *Lessons* into a semblance of life again, the more because the book was not only the most popular and widely used, but the most useful text-book of its day; one whose admirable lucidity and directness may well be the envy of the text-book makers of a later generation. It earned for itself an honorable name and a secure place in memory, and should now be allowed to pass, albeit with something of the same regret and sense of loss as at the death of its loved and lamented author. The attempt to combine its method and the modern one is a mistake, as false in theory as it is likely to be futile in practice. Mr. Bergen recently attempted a similar feat in his *Foundations of botany*, offering the old in one hand and all varieties of the new in the other. Authors (perhaps we should say in this case departments of botany) ought to be content to adopt a method which seems to them best, maintain it consistently through the book, and offer it with the other books, written from a similar or a different standpoint, for the intelligent choice of teachers. The other course savors of the commercial rather than the scientific or educational.—C. R. B.

MINOR NOTICES.

EUG. WARMING[5] has published an account of the very peculiar floral structures of certain Brazilian Burmanniaceae discovered by Dr. A. Glaziou, including a description of two new genera (*Glaziocharis* and *Triscyphus*) by Taubet.—J. M. C.

O. A. FARWELL has published a catalogue of the flora (Pteridophytes and Spermatophytes) of Detroit, being a reprint, with additions, from the Eleventh Annual Report of the Commissioners of Parks and Boulevards. It contains a total of 885 species and varieties.—J. M. C.

THE REPORT of the State Botanist of New York for 1900 has just appeared. It contains descriptions of forty-five new species and varieties of fungi. A section on edible fungi describes sixteen forms, three of which are new. Most of the new and edible species are illustrated in the thirteen colored double plates.—J. M. C.

A NEW FASCICLE[6] of Urban's *Symbolae Antillanae* has appeared. The first part (pp. 1–13) is a continuation of the botanical bibliography of the West Indies. The second (pp. 14–158) is a very interesting and apparently complete series of biographical notes of botanists who have visited the West

[5] WARMING, EUG., Sur quelques Burmanniacées recueillies au Bresil par le Dr. A. Glaziou. Bull. Acad. Roy. Sci. Danemark pp. 173–188. *pls. 3–4. figs. 1–6.* 1901.

[6] URBAN, IGNATIUS, Symbolae Antillanae seu fundamenta florae Indiae occidentalis. Vol. III. fasc. I. pp. 1–160. Leipzig: Gebrüder Borntraeger. 1902. *M* 9.

Indies. The last two pages begin the presentation of Piperaceae by C. de Candolle.— J. M. C.

THE THIRD FASCICLE[7] of Halácsy's *Flora of Greece* has appeared, completing the first volume. The previous parts were noticed in this journal for April (p. 290) and December (p. 419). The present part includes from Crassulaceae to Dipsaceae, and closes with a full index of the whole volume. The first fascicle[8] of the second volume has also appeared, containing the Compositae complete, and the beginning of Campanulaceae.— J. M. C.

THE SECOND, THIRD, AND FOURTH FASCICLES of the fifth volume of Thomé's *Flora von Deutschland* have appeared. As stated in a notice of the first fascicle (BOT. GAZ. 33: 71. 1902), this volume deals with cryptogams, excepting pteridophytes, which appeared in the first volume, and is the work of Dr. Walter Migula. The three fascicles received continue the presentation of the mosses, and contain twenty-three plates, eight of which are colored.— J. M. C.

THE SIXTH FASCICLE[9] of Engler's great work on the genera and families of African plants has just appeared, containing the Anonaceae by Engler and Diels. Twenty-two genera are recognized, three of which (*Asteranthe*, *Meiocarpidium*, and *Uvariastrum*) are described as new, and related to the largest genus, *Uvaria*, which includes forty-nine species. Numerous new species are described, and the thirty lithograph plates are models for such illustration.— J. M. C.

THE SECOND EDITION of Dörfler's useful directory of botanists[10] has just been issued. It has the same form and arrangement as the now well-known first edition. This one, however, contains 9,815 addresses, as against 6,455 in the first. The increase, both in number and accuracy, of the addresses in the United States is very marked. Mr. Dörfler renders the botanical world a distinct service in this publication — a service whose drudgery no one can appreciate who has not been through it. As the volume is published at his own risk botanists can reduce this and benefit themselves by purchasing a copy.— C. R. B.

[7] HALÁCSY, E. DE, Conspectus Florae Graecae. Vol. I. fasc. III. pp. 577–825. Leipzig: Wilhelm Engelmann. 1901. *M* 5.

[8] *Idem*. Vol. II. fasc. I. pp. 1–256. 1902. *M* 6.

[9] ENGLER, A., Monographien afrikanischer Pflanzenfamilien und Gattungen. VI. Anonaceae, bearbeitet von A. Engler und L. Diels. 4to. pp. 96. *pls. 30*. Leipzig: Wilhelm Engelmann. 1901. *M* 22.

[10] DÖRFLER, J., Botaniker-Adressbuch, Sammlung von Namen und Adressen der lebenden Botaniker aller Lander, der botanischen Gärten und der die Botanik pflegenden Institute, Gesellschaften und periodischen Publicationen. Zweite, neu bearbeitete und vermehrte Auflage. 8vo, pp. x + 356. Wien: J. Dörfler, III, Barichgasse 36. 1902.

THE PARTS of Engler's *Pflanzenreich* are appearing with remarkable rapidity. The eighth has now been published,[11] containing the Aceraceae (family 163 of the spermatophyte series) by F. Pax. The two genera are *Dipteronia*, a monotypic Chinese genus, and *Acer* with 114 species, 8 of which are new. The monograph is admirable in its painstaking care. Thirteen sections of *Acer* are recognized as follows: I. *Spicata* (30 spp.), II. *Palmata* (6 spp.), III. *Trifoliata* (6 spp.), IV. *Integrifolia* (6 spp.), V. *Indivisa* (9 spp.), VI. *Rubra* (4 spp.), VII. *Negundo* (3 spp.), VIII. *Glabra* (1 sp.), IX. *Platanoidea* (13 spp.), X. *Campestria* (10 spp.), XI. *Macrantha* (12 spp.), XII. *Lithocarpa* (9 spp.), and XIII. *Saccharina* (5 spp.). At the close of each section the geographical distribution is given and also the fossil forms. One map shows the distribution of the thirteen sections, and another the distribution of the fossil groups.—J. M. C.

DR. GY. ISTVANFFI[12] has produced a monumental work in publishing with editorial notes and commentaries the mycological classic of Charles de l'Escluse. This work, whose full title is "Fungorum in Pannonis Observatorum Brevis Historia," was published over 300 years ago, and is the foundation of Hungarian fungology and, to the honor of that country, the first scientific essay on mycology. Istvanffi's paper is a large quarto volume consisting of the following seven parts: (1) an exact reproduction of the *Fungorum Historia*, (2) historical investigations on the origin of the code and the determination of species, (3) biographical notes and an autobiographical sketch of l'Escluse, (4) a synoptical table of species, (5) the correspondence of l'Escluse, (6) catalogue of letters addressed to him, (7) the reproduction of the code with chromolithographic facsimiles of the original water-color sketches. These last are very interesting, and apparently executed with great accuracy. When not presenting original manuscripts Istvanffi has written in Magyar, followed immediately by a translation in French.— B. M. DAVIS.

THE SEVENTH PART of Wiesner's *Die Rohstoffe des Pflanzenreiches*[13] was issued in December last. The seventeenth section on Woods (to which the previous part was devoted) is completed, and the treatment of fibers begun. This section is by the author himself. The anatomical structure, physical and chemical characteristics, and methods of identification by polarization colors, anatomical peculiarities, and microchemical tests are described. A synopsis of fiber plants follows, the phrase being liberally construed as shown by the inclusion of such plants as *Zostera marina* (used in Venice for packing

[11] ENGLER, A., Das Pflanzenreich. Regni vegetabilis conspectus. Heft 8. Aceraceae von F. Pax. pp. 89. Leipzig: Wilhelm Engelmann. 1902. *M* 5.

[12] ISTVANFFI, Études et Commentaires sur le Code de l'Escluse. Budapest. 1900.

[13] Volume II. pp. 161–320. *figs. 45–75*. Leipzig: Wilhelm Engelmann, 1901. *M*. 5.

glassware), Eriophorum, Salix, and Epilobium (on account of the bristles and coma). The major part of the section, however, is devoted to an account of 43 fibers used in the arts. Only 9 of these are treated in the present part. The eighth part[14] has just appeared, completing the account of the fibers referred to above, and beginning the nineteenth section on subterranean parts. This section is an abstract of a paper prepared by Dr. A. E. v. Vogel, professor of pharmacognosy and pharmacology in the University of Vienna.—C. R. B.

THE AMOUNT of injury caused by oat smut in Wisconsin in the year 1901 is estimated by Professor R. A. Moore[15] in a recent bulletin to be $6,387,500, estimating the value of a bushel of oats at 35 cents. These figures were obtained as the result of careful estimates of the percentage of smut on 173 farms in 16 counties of the state by the author of the bulletin, and on 124 farms in 28 counties by former students, representing in all observations in 33 counties in the state. The latter's estimates gave an average of 15 per cent. smutted stalks, while the author's calculations, made ten days later, when the smut had more fully developed, gave 20 per cent. The determination was made by throwing a barrel hoop at random into a field and counting the total number of stalks inclosed and the number of those affected with smut. Several determinations were made in each field. It was found that fields sown with oats that had been soaked, and dried, before sowing for twenty minutes in a solution of one pound of 40 per cent. formalin in fifty gallons of water were entirely free from smut, even when grown beside fields not so treated and accordingly very badly smutted.—ERNST A. BESSEY.

THE FIRST PART of the studies "On the relation of phyllotaxis to mechanical laws," by Arthur H. Church, was noticed in this journal (**32**: 427. 1901), in which the theory was elaborated that "the arrangement of lateral members on a shoot-apex is possibly the expression of the symmetrical or asymmetrical distribution of growth-energy in the growing apex, and in a system for which uniform growth is postulated the appearances are to be mapped in terms of the phenomena of vortex construction, and represented graphically by the same geometrical construction as the lines of equal pressure and flow in circular or spiral vortices respectively." Such conditions of uniform growth do not usually obtain in a growing apex, but their consideration must precede that of varying and diminishing rates of growth. In the second part,[16] now before us, the special cases of phyllotaxis are considered

[14] Volume II. pp. 321–480. *figs. 76–155.* 1902. *M* 5.

[15] MOORE, R. A., Oat smut in Wisconsin—prevalence and method of eradication. Bulletin 91 Wisc. Agr. Expt. Sta. pp. 15, *figs. 2*, F 1902, Madison.

[16] CHURCH, A. H., On the relation of phyllotaxis to mechanical laws. Part II. Asymmetry and Symmetry. pp. 79–211. *pls. 11–25. figs. 36–80.* Oxford: Williams and Norgate. 1902. 5s.

under the following heads: (1) Asymmetry of the normal Fibonacci series, (2) Symmetrical construction, in which the Fibonacci ratios are lost, (3) The special case of "least concentrated" asymmetry, (4) Non-concentrated symmetry, (5) Multijugate systems, and (6) Anomalous systems. Subsequent sections will include the consideration of secondary disturbances in the primary system, the relations of dorsiventral primordia, deductions from the mathematical investigations of the log. spiral systems, and the relation of all these factors to the interpretation of floral structures in the form of floral diagrams.—J. M C.

NOTES FOR STUDENTS.

L. GUIGNARD[17] has discovered "double fertilization" to be a common phenomenon among the Ranunculaceae. To the species he had previously announced in 1900 (*Caltha palustris*, *Ranunculus Flammula*, *Helleborus foetidus*, *Anemone nemorosa*, *Clematis Viticella*, and *Nigella sativa*) he now adds *Nigella Damascena* and *Ranunculus Cymbalaria*. Nawaschin published double fertilization in *Delphinium elatum* two years ago. Double fertilization, therefore, may be regarded as a general habit among Ranunculaceae.—J. M. C.

DAVID GRIFFITHS[18] has described the self-burial of the seeds of *Plantago fastigiata* in the desert region of southern Arizona. His conclusion is that the function of the mucilage is the burial of the seed, and that it is accomplished by the tension set up owing to the contraction of the expanded mucilage which has become firmly attached around its outer and lower edges to the particles of soil into which it has penetrated, resulting in a compacting of the soil immediately below the seed and its coat so as to form a pit into which the seed is forced. The cup-shaped depression is subsequently filled with earth by entirely external influences.—J. M. C.

IN A RECENT CONTRIBUTION[19] from the Gray Herbarium, M. L. Fernald presents the northeastern Carices of the section Hyparrhenae, reaching conclusions very different from those generally accepted by American caricologists. After discussing in considerable detail the more important questions, he presents a synopsis of the forty-one recognized species, including descriptions of four new species and ten new varieties. In the second part of the contribution the variations of some boreal carices are discussed, the species being *C. aquatilis*, *C. pilulifera*, *C. communis*, *C. pennsylvanica*, *C. umbellata*, *C. vaginata*, *C. saltuensis*, and *C. capillaris*.—J. M. C.

[17] Double fécondation chez les Renonculácees. Jour. Botanique **15**: 394-408. *figs. 1–16*. 1901.

[18] A novel seed planter. Bull. Torr. Bot. Club **29**: 164-169. 1902.

[19] FERNALD, M. L., Contributions from the Gray Herbarium of Harvard University. New Series, no. 22. Proc. Amer. Acad. **37**: 447–514. *pls. 1–5*. 1902.

RECENTLY Zimmermann[20] has described some remarkable bacterial nodules which occur in leaves of various Rubiaceae (*Panetta lanceolata*, *P. angustifolia*, *P. indica*, and *Grumilea micrantha*). These nodules consist of masses of spongy parenchyma, the intercellular spaces of which are filled with bacteria. No mention is made whether the bacteria in any way affect the cell walls. The author supposes that the bacteria get into the leaves through a stomate which he finds immediately above each nodule on the upper leaf surface. He made no determination as to a possible causal relation between the nodules and the bacteria, reserving this for further study.—H. v. SCHRENK.

F. W. OLIVER[21] has described a sporangium of one of the paleozoic ferns, in which an interrupted ring of tracheal elements occurs between the wall and the sporogenous tissue, in the position of a tapetum. The tracheae are rather thin-walled and exhibit well-marked pits of the reticulate type. He is inclined to refer the sporangium to the Botryopterideae, and since these ferns hold certain anatomical relations to the Cycadofilices, this vascular sporangium becomes suggestive of the possible character of the unknown sporangia in the latter group. Of course the occurrence of tracheal elements in the megasporangia of gymnosperms and certain angiosperms is well known.—J. M. C.

A. C. SEWARD and ELIZABETH DALE[22] have described the four species of Dipteris, a genus of eastern Asiatic and East Indian ferns, giving full synonymy; have presented in detail the anatomical structure of *D. conjugata*; in discussing the affinities of the genus as indicated by anatomical characters, and combining these characters with those presented by the sporangium and the form and venation of the fronds, have reached the opinion that Dipteris should be removed from the Polypodiaceae and included in a separate family, of which it represents the solitary surviving type; and have traced the geological history of the genus, which supports the statement that the species of Dipteris are remnants of a family with a wide European distribution during the earlier part of the Mesozoic.—J. M. C.

IN STUDYING THE EMBRYO of Nymphaea, Henry S. Conard[23] has had occasion to compare it with that of Nelumbo as recently described by H. L. Lyon and noted in this journal (**33**: 165. 1902.) There is in both the same "spherical embryo" consisting of hundreds of cells, but in Nymphaea there is also a suspensor of three to five cells in linear series. In Nymphaea the

[20] ZIMMERMANN, A., Über Bacterienknoten in den Blättern einiger Rubiaceae. Jahrb. Wiss. Bot. **37**: 1. *figs. 9.* 1901.

[21] On a vascular sporangium from the Stephanian of Grand 'Croix. The New Phytologist **1**: 60–67. *pl. 1.* 1902.

[22] On the structure and affinities of Dipteris, with notes on the geological history of the Dipteridinae. Phil. Trans. Roy. Soc. London **194**: 487-513. *pls. 47-49.* 1901.

[23] Note on the embryo of Nymphaea. Science **15**: 316. 1902.

spherical mass of cells gives rise to two opposite and distinct cotyledons, with the plumule between them. Later the cotyledons become hemispherical and concave, applied against each other all round by the edges, and enclosing a central cavity occupied by the plumule. This seems to indicate that the embryo of Nelumbo must be regarded as dicotyledonous and unsymmetrical, rather than monocotyledonous with a two-lobed cotyledon.—J. M. C.

GEORGE H. SHULL[24] has made a quantitative study of variation in the bracts, rays, and disk florets of certain species of Aster. His conclusions are that there is a close correlation between bracts and rays, arising from the fact that the rays are axillary to the bracts; that the degree of imbrication of the bracts bears a relation to the number of empty bracts; that in a single group of specimens of *A. prenanthoides* the number of bracts, rays, and disk florets decreases continuously from the beginning to the end of the flowering season; and that the character of the curves and the position of their means and modes likewise change continuously. Curves and constants were determined for the material studied; and constants determined for several individuals of *A. punicus*, growing in identical surroundings, indicated how great variations may exist in the variability constants of individuals.—J. M. C.

IN HIS THIRD PAPER[25] on American ferns, Professor Underwood discusses the order of their relative importance, are (1) type of venation, (2) habit and growth characters of stem, (3) position of sori in relation to veins, and (4) indusial characters. His history of the migration and shifting of generic names and limits reveals a tangled mass of nomenclature, and proves the necessity of some agreement for anchoring generic names. The fifteen American genera of Aspidieae, only three of which are represented in the Northern States, are recognized as follows: *Leptogramma* J. Sm., *Phegopteris* Fée, *Plecosorus* Fée, *Polystichum* Roth., *Cyclopeltis* J. Sm., *Didymochlaena* Desv., *Camptodium* Fée, *Dryopteris* Adans., *Phanerophlebia* Presl, *Goniopteris* Presl, *Meniscium* Schreb., *Cyclosorus* Link, *Fadyenia* Hook. & Baur, *Tectaria* Cav., and *Sagenia* Presl.—J. M. C.

ANOTHER PAPER proving that the pollen mother cell of Asclepias gives rise to four microspores has just appeared.[26] Strasburger[27] and Frye,[28] whose

[24] A quantitative study of variation in the bracts, rays, and disk florets of *Aster Shortii*, *A. Novae-Angliae*, *A. puniceus*, and *A. prenanthoides*, from Yellow Springs, Ohio. Amer. Nat. **36**: 111–152. 1902.

[25] Bull. Tor. Bot. Club **29**: 121–136. 1902.

the genera of Aspidieae. The several characters he takes into account, in

[26] GAGER, C. S., The development of the pollinium and sperm cells in *Asclepias Cornuti*. Annals of Botany **16**: 123–148. *pl.* 7. 1902.

[27] STRASBURGER, E., Einige Bemerkungen zu Pollenbildung bei Asclepias. Ber. Deutsch. Bot. Gesells. **19**: 450–454. 1901.

[28] FRYE, T. C., Development of the pollen in some Asclepiadaceae. BOT. GAZ. **32**: 325–330. *pl.* 13. 1901.

work was done independently and whose results were published almost simultaneously about six months ago, made it plain that the mother cell gives rise to a row of four microspores. Both writers based their conclusions upon a cytological study of the mother cell, and the mitoses which occur as the mother cell gives rise to the four spores. Mr. Gager traverses about the same ground and arrives at the same conclusions. Four years ago W. C. Stevens[29] made the statement that "in *Asclepias Cornuti* the pollen mother cell divides twice, producing a radial row of four pollen grains." The statement is made as if the writer were referring to an accepted fact, and not as if he were making a contribution. Being referred to in this incidental way, in a paper devoted to a study of the kinoplasm and nucleolus, this unconscious contribution might possibly have been overlooked even if it had appeared in a journal of wide circulation; but appearing as it did in a university quarterly, it was as thoroughly buried as if it had been published in an agricultural bulletin. Real contributions to morphology or cytology are so infrequent in such publications that they are almost sure to be lost unless the investigator happens to recall them on account of personal copies among his separates. Any one of the four papers is sufficient to prove conclusively that in Asclepias the pollen mother cell gives rise to four pollen grains, instead of being transformed directly into a single pollen grain, as was formerly supposed.—CHARLES J. CHAMBERLAIN.

ITEMS OF TAXONOMIC INTEREST are as follows: B. L. ROBINSON (Rhodora **4**: 65–73. *pl. 35*. 1902), in presenting the New England species of Polygonum of the section Avicularia, has described a new species (*P. Fowleri*).—ARTHUR BENNETT (Jour. Bot. **40**: 145–149. 1902), in continuing his "Notes on Potamogeton," describes two new species (*P. rectifolius* and *P. strictifolius*) from the United States.—E. L. GREENE (Ottawa Nat. **16**: 32–34. 1902) has published five new species of Ranunculus from various regions of the United States and Canada.—N. L. BRITTON (Torreya **29**: 43. 1902) has described a new Peperomia from the Island of St. Kitts, British West Indies.—TAUBERT (Bull. Acad. Roy. Sci. Danemark. pp. 175–179. *pls. 3–4*. 1901) has described two new Brazilian genera (*Glaziocharis* and *Triscyphus*) of Burmanniaceae from the collections of Dr. A. Glaziou.—PH. VAN TIEGHEM (Jour. Botanique **15**: 389–394. 1901) has described a new Brazilian genus (*Epiblepharis*) which belongs with Luxembourgia in the family (Luxembourgiaceae) he has set apart from Ochnaceae. He has also described (*idem* **16**: 33–47. 1902) three additional new genera (*Setouratea*, *Campylospermum*, and *Bisetaria*) of Ochnaceae.—P. A. RYDBERG (Bull. Torr. Bot. Club **29**: 145–160. 1902), in his seventh paper entitled "Studies on the Rocky mountain flora," describes new species

[29] STEVENS, W. C., The behavior of the kinoplasm and nucleolus in the division of the pollen mother cells of *Asclepias Cornuti*. Kansas Univ. Quarterly **7**: 77–85. *pl. 15*. 1898.

of Aquilegia (4), Delphinium (5), Aconitum (4), Anemone (3), Clematis (2), Atragene (3), Ranunculus (4), Papaver, Argemone and Bicuculla.—G. E. OSTERHOUT (*idem* 173–174) has described a new species of Hesperaster from Colorado.—ELSIE M. KUPFER (*idem* 137–144. *pl. 8*), in studies of certain genera of Pezizineae, reestablishes Urnula, determines the relationship between Geopyxis and Urnula, and establishes the new genus *Chorioactis* (Pezizaceae). —J. M. C.

WILLIAM H. LANG[30] has been able to secure in Ceylon abundant prothallia of *Ophioglossum pendulum* and *Helminothostachys zeylanica* for study. The subterranean, tuberous, saprophytic character of the gametophyte of Ophioglossaceae is well known, and in the main these studies bear out those of Campbell and Jeffrey on Botrychium. In Ophioglossum the prothallium is usually branched, the short branches radiating in all directions; while in Helminthostachys there is a lobed basal portion from which arises a cylindrical process bearing the sex organs. In both an endophytic fungus is present. The antheridia and archegonia, so far as their development and structure were determined, present no new features. The author discusses the problematical relationships of the Ophioglossaceae, from the standpoint of the gametophyte, including its anatomy. He is inclined to believe that there are no constant characters of morphological value that indicate affinity between Ophioglossaceae and the Lycopodiales. On the other hand, the form of the prothallium, the structure of the sexual organs, and the embryogeny of the Ophioglossaceae are to the author such as might be expected in saprophytic forms derived from prothallia of the general type found among Filicales.

In this same connection reference should be made to the alga-like prothallium of *Schizaea bifida*, an Australian fern described by A. P. W. Thomas,[31] A similar prothallium has been described by Mrs. Britton and Miss Taylor for *S. pusilla*, as noted in this journal (**31**: 363. 1901). The prostrate filaments give rise to erect ones that branch profusely, rising to a height of 3–4^{mm}. These prothallia differ from the well-known filamentous ones of Trichomanes in that they are completely filamentous throughout, the venter of the archegonium being entirely free, and even narrowed at the base, remarkably resembling the archegonia of bryophytes in this regard. —J. M. C.

THE QUESTION OF ABSORPTION AND EXCRETION of water and solutes by foliage leaves has been made the subject of a long and varied series of

[30] On the prothalli of *Ophioglossum pendulum* and *Helminthostachys zeylanica*. Annals of Botany **16**: 23–56. *pls. 1–3*. 1902.

[31] An alga-like fern prothallium. Annals of Botany **16**: 165–170. 1902.

experiments by Dandeno.[32] His most important conclusions are as follows:

1. Wilted leaves absorb water when their surface is wet with this substance.

2. Solutes are absorbed in the same way. Certain plants (*e. g.*, Thunbergia, Justicia) may be so arranged as to take up in this manner all the solutes necessary for growth. In the case of Justicia, plants whose leaves were supplied with solutes for seventeen days contained at the end of that time ash to the amount of 17.89 per cent. of their dry weight; similar plants not so supplied contained only 16.37 per cent. of ash.

3. Solutes diffuse outward from leaf tissues when the surface of the leaves is wet with water. These may be resorbed as stated under 2. Guttation drops (tomato, Impatiens, Phaseolus, etc.) and dew drops upon leaves contain salts, mainly $CaCO_3$. When evaporation is too rapid for complete resorption to take place, incrustation results. Distilled water left in contact with living leaves usually becomes alkaline.

4. Solutions applied to the cut end of the petiole of a detached leaf are absorbed and transmitted throughout the leaf. If they have a bad effect upon the leaf, this may be in one of two ways: (*a*) osmotically they may extract water from the leaf cells, thus causing plasmolysis and evident translucence of the affected parts through the presence of water in the intercellular spaces; (*b*) they may affect the cells in a chemical way, in which case no translucence is produced. Ascent in the veins takes place at a rate proportional to the length of the veins; the outline of the affected portion of the leaf is at any time similar to that of the whole leaf.

5. Cut twigs of Salix in early spring show more rapid and better development of the buds when supplied with distilled water than when supplied with a nutrient medium. It is immaterial where this water is absorbed, whether through young leaves, through the cut ends of the twig, or through roots which have grown out. Water cannot be absorbed through the bark.

The experiments are not well summarized, and theoretical suggestions are jumbled with demonstrated facts, so that the paper is difficult to read. The methods by which the experimentation was conducted are quite fully described, and for the points enumerated above they appear sufficient. But several other series of experiments are so unsatisfactory that it seems as though they might have been omitted with an increased clearness of the article as a whole. A rather copious literature is cited, but poorly cited, titles and references being incompletely given.—BURTON E. LIVINGSTON.

[32] DANDENO, J. B., An investigation into the effects of water and aqueous solutions of some of the common inorganic substances on foliage leaves. Transactions of the Canadian Institute 7: 238–350. 1901.

IN HIS PAPER on causes governing the direction of branch growth Baranetsky[33] presents some new results of experimentation in this field. The author used entire plants, a number of woody and several herbaceous species being brought into requisition. The stems and branches were first bent into various positions and held thus until a geotropic growth curve had resulted, after which the plants were freed and placed upon a revolving klinostat. One of the most important results of the study of these rotating plants is the discovery of what is termed "opposite bending." By this the author means that phenomenon wherein the plant not only straightens a previously formed geotropic curve, but passes the original vertical position and bends in the opposite direction. After the first opposition curve is formed, a return to the original curvature may result, giving a pendulum-like motion of the tip, which exhibits several vibrations of gradually decreasing amplitude, until at length the normal position is reached. Such curving is ascribed to an accelerated growth on the concave side, of sufficient vigor to throw the tip beyond its first position. This then stimulates growth on the new concave side, but with lessened intensity, thus producing the vibration just noted. In his explanation of this opposition curve Baranetsky differs from Vöchting and Czapek, who hold that the increased growth on the concave side is merely sufficient to return the tip to its original position. Baranetsky also suggests that growth on the concave side may be aided by an inhibition on the convex side due to stretching of the cells.

Baranetsky carried on observations in the field as well as by laboratory experiments. The forms studied, are divided according to their behavior into three types: the Prunus type includes Aesculus and Euonymus; the linden type includes Ulmus, Fagus, Crataegus, Celtis, and Corylus; and the needle-leaf type includes the pines. The first group is characterized by the upward turning of the side buds, the second by their downward turning, and the third by the wavy branches and sharply turned up tips. For the first type the author states the four following points: (1) physiological bilaterality is absent; (2) lateral shoots behave as main shoots; (3) all shoots are negatively geotropic; and (4) each curve produces an opposition curve which may either lessen or overcome the geotropic curvature. For the second and third types he finds (1) that weight plays an important part in directing the position of branches; (2) that geotropism is very powerful, often forcing the tips to a vertical position even in nature; (3) that epinasty is so slight that it cannot overcome or greatly lessen the geotropic curve.

In general, the author finds that the response to geotropism varies greatly in different species even within the same genus. Nowhere was it found that a weight stimulus caused growth.— P. G. WRIGHTSON.

[33] BARANETSKY, J., Ueber die Ursachen, welche die Richtung der Aeste der Baum- und Straucharten bedingen. Flora **89**: 138–239. 1901.

DR. H. J. WEBBER in an interesting paper[34] gives the results of his further studies of *Zamia*. The two Florida species, *Z. floridana* DC. and *Z. pumila* L., were formerly incorrectly referred to *Z. integrifolia* Jacq.

It is an interesting fact that development proceeds normally for several days after the strobili have been removed from the plants, so that even living spermatozoids may be secured from such material. The movements of the spermatozoids were studied in a sugar solution.

Although the germination of the microspores was not studied in detail, it is probable that there is an evanescent prothallial cell in addition to the persistent prothallial cell and antheridial cell (second prothallial cell of the author) which are conspicuous in the mature pollen grain. After the division of the antheridial cell to form the stalk and body cells, the persistent prothallial cell and the stalk cell become filled with starch and the former arches into the latter so that there is often the appearance of one cell entirely surrounding the other. The blepharoplasts first appear in the body cell (central cell) and are formed *de novo* from the cytoplasm. They are at first very small, being scarcely more than points where a few radiating filaments converge, but as they increase in size, a surrounding membrane and vacuolated contents can be seen. Shortly before the division of the body cell, the nucleus passes through a synapsis stage which is regarded as normal and not at all due to reagents. The spindle is developed while the nuclear membrane is still intact. It is apparently entirely of nuclear origin and none of the fibers have any connection with the blepharoplasts. During the equatorial plate stage, the blepharoplasts break up and in an early anaphase the contents have entirely disappeared, while the outer membrane soon breaks up into numerous granules, which during the formation of the cell plate begin to fuse, thus forming the cilia-bearing band. At first, the band is located in the cytoplasm midway between the nucleus and the periphery of the cell, but it ultimately moves out and becomes appressed to the plasma membrane, where it forms a helicoid spiral of from five to six turns. The entire spermatid is metamorphosed into a spermatozoid, there being no differentiation of a spermatozoid within a mother cell. The mature spermatozoids are the largest known in any plant or animal, being visible to the naked eye. They move mainly by means of cilia, but there is also an amoeboid movement of the spiral end.

In fertilization the entire spermatozoid enters the egg, but the nucleus soon slips out from the cytoplasmic sheath, leaving the ciliiferous band in the upper part of the egg. The nucleus moves on and fuses with the egg nucleus. There is a fusion of cytoplasm with cytoplasm and nucleus with nucleus.

[34] WEBBER, H. J.: Spermatogenesis and fecundation of Zamia. U. S. Dept. of Agriculture, Bureau of Plant Industry. Bull. no. 2. pp. 1–100. *pls.* 1–7. 1901.

Webber still believes that the blepharoplast is not the homologue of the centrosphere or centrosome because it differs from the centrosome "(1) in not forming the center of an aster at the pole of the spindle, being located entirely outside of the spindle in Zamia, Cycas, and Gingko; (2) in having no connection with spindle formation; (3) in being limited to the division of a single cell, thus to one cell generation, no similar organ appearing in any other stage of the plant's development, so far as known; and (4) in having a function differing from that of any typical centrosome, so far as known in plants."—CHARLES J. CHAMBERLAIN.

THE TRANSMUTATION THEORY of Darwin does not, according to Korschinsky,[35] explain how variations come about nor the origin of new forms. As a study of the wild forms alone could not solve the problem, he turned to the cultivated plants for a solution, and asserts for the latter that "no breeder has ever operated with individual variations for the production of new races, and that there has never been observed a heaping up of such variations. On the other hand, all new varieties (with the exception of crosses) whose origin is known developed as sudden variations of true species or hybrid forms." May not these sudden variations play the same rôle in nature, and may not this be an explanation of the discrepancies between the nature and occurrence of variations and the Darwinian theory?

The existence of sudden variations was well known to Darwin, but he laid little stress on these, holding them to be abnormal and exceptional. This sudden appearance Korschinsky calls "heterogenesis," and hopes to show that it is "though a rare yet completely normal phenomenon among plants and animals, and plays in their development an extraordinarily important rôle." The characteristics of heterogenesis is the topic of this paper, to be followed by another in which its rôle in the origin of species is to be treated.

The history of the term "heterogenesis" is traced to Kölliker and his explanation given, whereupon many cases of sudden variations are brought up and discussed. The sources are mainly French. He sums up to show that there appears suddenly a new race as fixed and as constant as those existing from immemorial time. Some persons have explained these as cases of atavism, others as monstrosities; but Korschinsky believes that "heterogenesis often makes it possible for atavism to show itself," and again that "the manifestation called heterogenesis shows itself in the unexpected appearance of different variations from the typical structure. Functional disarrangement of organs is an accompaniment of some, and these are monstrosities; other variations, however, do not disturb the vital functions of

[35] KORSCHINSKY, S., Heterogenesis und Evolution. Ein Beitrag zur Theorie der Entstehung der Arten. Translated from the Russian by S. Tschulok of Zürich. Flora 89: 240–363. 1901.

the organism and give rise to particular races." Considering all morphological peculiarities and physiological qualities as the results of heterogenesis, we must acknowledge that they do not differ in general from other types or races existing from time immemorial, and which latter, based on the Darwinian theory, we ascribe with confidence as having developed by means of a slow heaping up of characteristics and continuous selection. As, however, we know nothing of the way by which the forms of all wild and the greater proportion of cultivated plants have come about, there comes the question: Is the event of the development of new forms by way of heterogenesis so seldom and exceptional? Does it not occur oftener than we think, and does it not play a certain rôle in the evolution of forms in the plant kingdom? He takes up variability in garden plants under the most prominent forms, and discusses the many observations that have accumulated. Some of his main topics are variations of growth, variations of stem, of crowns, form of leaves, color of leaves, color of flowers, in structure of flowers, variations in blooming, and in fruits. On the basis of this study the peculiarities of heterogenetic characteristics are to be found in the more or less prominent variations readily distinguished from the combinations of unimportant variations which make up an individual in a group of its kind; that is, in the absence of hybridity or heterogenesis, there will be no characteristics radically distinguishing one individual from another.

The direction of variability and the characteristics of heterogenetic variation bring out an interesting discussion of sports. It is characteristic of heterogenetic variations that they are constant, not only by vegetative reproduction, but also when propagated from seed, although, especially in the first generations, some aberrant forms may appear.

Inheritance and variability, whatever their real causes, may be thought of as two forces hidden in the organism, as two antagonistic tendencies. Under normal conditions, we have the identity of succeeding generations, but the tendency to vary is not constant. "It (the tendency to vary) must, so to say, gather the necessary energy during many generations in order finally to overcome the power of inheritance and to give rise to a heterogenetic race." The mechanism resulting in this appearance must be sought in the changes taking place in the sexual products, that is, either in the pollen or in the ovule. It seems probable that the variations are initiated during or after fertilization. The cause of this change, and why one ovule and not another is influenced, remains completely inexplicable.

The list of references at the close covers five and one-half pages.—G. N. LAUMAN.

NEWS.

A CHAIR OF BACTERIOLOGY in the University of Edinburgh has been endowed by the will of Mr. Robert Irvine.

PROFESSOR FLAHAULT, the well known botanist at Montpellier, has been chosen Chevalier of the Légion d'Honneur.

DR. JOHANNES CHRISTOPH KLINGE, of the botanical gardens at St. Petersburg, recently died at the age of fifty-one.

DR. C. S. BELLI, formerly of Turin, has been appointed professor of botany and director of the botanical gardens at Cagliari.

DR. F. CAVARA, formerly of Cagliari, has been appointed professor of botany and director ot the botanical gardens at Catania.

A VERY INTERESTING ACCOUNT of the palm trees of Brazil has been published in *Popular Science Monthly* for March by Professor John C. Branner of Stanford University.

DR. B. E. FERNOW, director of the New York State College of Forestry, will deliver a course of lectures on forestry at the University of California in the coming summer session.

PROFESSOR G. POIRAULT, director of the laboratory at Villa Thuret, has been elected professor at l'École Nationale d'Horticulture de Versailles in place of Professor Cornu, deceased.

THE DANISH GOVERNMENT, which has done so much for the exploration of western Greenland, has sent a party to the east coast for the purpose of botanical exploration. Dr. Kruuse is the director of the expedition.

THE SEVENTY-SECOND ANNUAL MEETING of the British Association for the Advancement of Science will be held at Belfast, beginning September 10. The president of the botanical section is Professor J. Reynolds Green.

THE ADDRESS of Dr. Erwin F. Smith as president of the New York meeting of the Society of Plant Morphology and Physiology, on "Plant pathology: a retrospect and prospect," is published in *Science* for April 18.

ATTENTION is called to the rules for citation printed on the page following the table of contents. It is to be hoped that every contributor, at least of leading articles, will be guided by them in his preparation of manuscript.

THE STOKES PRIZE for the best essay on the preservation of our native flora has been awarded for the current year to Dr. F. H. Knowlton. The

essay is printed in the March number of the Journal of the New York Botanical Garden.

PROFESSOR E. ZACHARIAS, formerly director of the botanic gardens in Hamburg, has been appointed director of the Government Botanical Institute of Hamburg, comprising botanical garden, museum, and laboratory for economic work.

PROFESSOR B. D. HALSTED has been compelled to give up his work for a time on account of illness, and as a consequence will not be able to give the presidential address at the meeting of the Botanical Society of America at Pittsburg.

ASSOCIATE PROFESSOR CUMMINGS has been placed in charge of the department of botany at Wellesley College since the retirement of Professor Hallowell from active service, and all correspondence intended for the department should be addressed to the former.

PROFESSOR A. N. BERLESE, professor of botany in the University of Sassari, has been appointed professor of vegetable pathology in the school of Agriculture at Milan. He is succeeded by Professor G. B. DeToni, now of the University of Camerino.

GEBRÜDER BORNTRAEGER announce a second edition of Warming's *Lehrbuch der ökologischen Pflanzengeographie*, revised and brought up to date by Dr. Paul Graebner, whose previous ecological studies amply equip him for a work of this importance.

THE ELEVENTH SESSION of the Hopkins Seaside Laboratory, in connection with Stanford University, will begin June 9. The following courses in botany will be given by Dr. A. A. Lawson: Elementary botany, Introduction to the study of seaweeds, Plant cytology and microtechnique.

THE HARVARD STATION in Cuba, at Colonia Limones, about twenty miles from Cienfuegos, is testing the possibility of repeating in the climate of Cuba the well-known Javan studies in the pollination of sugar-cane. The work is in charge of Robert M. Grey, an experienced hybridizer.

DR. D. T. MACDOUGAL, of the New York Botanical Garden, has returned from his trip to Arizona and Sonora with an extensive collection of giant cacti and other xerophytes for the garden. Dr. N. L. Britton, Director of the garden, has gone on a collecting trip to Cuba; and Professor F. S. Earle is also collecting for the garden in New Mexico and Texas.

IN THE SUMMER of 1902 two ecological expeditions will be sent out from the University of Chicago. Dr. H. C. Cowles will conduct a party to Mt. Katahdin and the coast of Maine at the close of the session of the Woods Hole Marine Biological Laboratory. Mr. Harry N. Whitford will conduct a party to Flathead Lake and the Montana Rocky mountains during the month of August.

A PRICE LIST of botanical laboratory supplies, recently published by the Marine Biological Laboratory, may be obtained from Mr. George M. Gray, Woods Hole, Mass. Special emphasis is given to marine algae, which are sold in sets mounted on cards for demonstration purposes, and also as preserved material for the laboratory. Types of fresh water algae, fungi, mosses, and liverworts are also offered.

A LIST of economic and other fungi prepared for distribution by the Division of Vegetable Pathology and Physiology has been published, prepared by Flora A. Patterson. Each state agricultural experiment station is invited to select fifty specimens from the list, and all over fifty may be considered as in exchange. The benefits of this exchange are extended also to all who are interested in the study of fungi from the economic standpoint.

IN THE LATTER PART of March Professor C. B. Davenport and Dr. H. C. Cowles of the University of Chicago conducted a party of students to the gulf coast of Mississippi. The party was joined by Professor S. M. Coulter of Washington University, Dr. W. S. Leathers of the University of Mississippi, and Mr. S. M. Tracy of Biloxi, Mississippi. Valuable collections were made of plant and animal material, and a considerable number of representative photographs were obtained.

IN *Ber. Deut. Bot. Gesells.* for March 10 biographical notices of six deceased members of the society appear. The notice of ALBERT BERNHARD FRANK, who died September 27, 1900, at the age of 61, is prepared by Friedrich Krüger; that of ROBERT HEGLER, who died September 29, 1900, at the age of 33, by G. Karsten; that of KARL DUFFT, who died October 11, 1900, at the age of 75, by Carl Holtermann; that of SSERGEI IWANOWITSCH KORSHINSKY, who died December 18, 1900, at the age of 39, by G. Tanfiljew; that of MAXIME CORNU, who died April 3, 1901, at the age of 57, by P. Magnus; and that of A. F. WILHELM SCHIMPER, who died September 9, 1901, at the age of 45, by H. Schenck. The last notice is accompanied by a portrait.